HUMAN PESTICIDE EXPOSURE ASSESSMENT

SIMAZINE

(A Selective Pre- and Post-Emergence Herbicide)

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ABSTRACT

This exposure assessment document is written as an integral part of the Department's risk characterization document for the active ingredient simazine. Simazine is a selective pre- and post-emergence herbicide used primarily for the control of broadleaf and grassy weeds in soil where almonds, apples, avocados, blueberries, corn, established Christmas trees, grapes, and other crops are or will be planted, and in non-cropped areas such as around buildings, lawns, and rights-of-way. Simazine is an organic compound of the *s*-triazine family. Its mode of herbicidal action is through inhibition of photosynthesis. During the five-year period between 2006 and 2010, there was one (1) illness reported in California as having an association with simazine use in combination with other pesticides, with the case occurring in an occupational setting and involving eye irritation as the only symptom. Available metabolism studies showed that a di-*N*-dealkylated metabolite appeared to be the major degradate in rats with a range from 1.6% of the applied (gavage) dose at 0.50 mg/mL to 18% at 50 mg/mL, tending to suggest that the rate of simazine metabolism in the rat may be dose-dependent. A study on dermal absorption of atrazine in humans was also submitted, from which a daily absorption of 6% was concluded to be an appropriate surrogate and sufficient for calculating the dermal doses of simazine in humans. In the present exposure assessment, the potential exposures to simazine were considered for 14 exposure scenarios subsumed under 6 major subpopulations including applicators, human flaggers, mixer/loaders, mixer/loader/applicators, homeowner users, and nonusers as well as bystanders. Reentry exposures for fieldworkers were deemed insignificant and hence not assessed quantitatively, as simazine is a herbicide used primarily for the control of weed seeds with a very short application window. No chemical-specific data on human exposure to simazine were available. The potential exposures to simazine for the subpopulations were thereby estimated from (considering the use of) surrogate exposure data, such as those available in the nonchemical-specific PHED (Pesticide Handlers Exposure Database) or those specifically on atrazine, a herbicide very similar to simazine in structure, functions, and uses. For short-term exposure lasting 1 to 7 days, the highest calculated absorbed daily dosage (ADD) was 5.5 mg per kg of body weight (BW), that estimated for aerial mixer/loaders preparing liquid simazine while wearing normal work clothes and gloves. For intermediate-term (a.k.a. subchronic) exposure (i.e., for 8 to 90 days), the highest calculated ADD was 1.4 mg/kg BW, also for the same handler group. For nonuser residents as well as for children with normal (or pica) mouthing behavior, the estimated aggregate ADD from short-term or subchronic exposure was <0.14 (or <0.16 for pica) mg/kg BW.

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ABBREVIATIONS AND ACRONYMS

AADD	annual average daily dosage
ADD	absorbed daily dosage
AI	active ingredient
ARB	California Air Resources Board
BSA	body surface area
BW	body weight
Cal/EPA	California Environmental Protection Agency
CAS	Chemical Abstracts Service
CCR	California Code of Regulations
CFAC	California Food and Agriculture Code
CFR	Code of Federal Regulations
CV	coefficient of variation
DFR	dislodgeable foliar residue
DPR	California Department of Pesticide Regulation
EQL	estimated quantitation limit
GM	geometric mean
IRED	Interim Reregistration Eligibility Decision
LADD	lifetime average daily dosage
LCO	lawn care operator
MCL	Maximum Contaminant Level
M/L/A (M/L/Applicator)	mixer/loader/applicator
NIOSH	National Institute for Occupational Safety and Health
NOEL	no-observed-effect-level
OEHHA	Office of Environmental Health Hazard Assessment
ORETF	Outdoor Residential Exposure Task Force
PHED	Pesticide Handler Exposure Database
PISP	Pesticide Illness Surveillance Program
PPE	personal protective equipment
PPM	parts per million
PUR	Pesticide Use Report
RCD	risk characterization document
RED	Reregistration Eligibility Decision
REI	restricted entry interval
SADD	seasonal average daily dosage
TTR	transferable turf residues
UCL	upper confidence limit
U.S. EPA	U.S. Environmental Protection Agency
WHS	Worker Health and Safety Branch
WP	wettable powder

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I. INTRODUCTION

Simazine is a selective pre- and post-emergence herbicide for the control of broadleaf and grassy weeds in soil where almonds, apples, avocados, blueberries, established Christmas trees, grapes, nectarines, olives, pears, pecans, strawberries, and other crops will be planted or are planted, and in non-cropped areas such as around buildings, lawns, and rights-of-way. This herbicide active ingredient (AI) was once used as an algaecide for control of aquatic weeds, in such places as farm ponds, fish hatcheries, and ornamental fountains. As of late April 2013, a total of 13 products containing simazine as the AI are actively registered in California. Simazine is readily absorbed through roots and is translocated to shoots via the apoplast (i.e., the non-living part of the root), including the xylem. Its mode of herbicidal action is through inhibition of photosynthesis. The herbicide is resistant to physical and chemical dissipation processes in the soil, and has a potential for leaching into ground and surface waters nearby. In response to the public concern over this leaching potential, Cal/EPA's Office of Environmental Health Hazard Assessment (OEHHA) has established a public health goal (i.e., a targeted level for public safety) of 4 μg/L for simazine in drinking water (Fan and Alexeeff, 2001).

Simazine is a white crystalline organic compound of the *s*-triazine family (i.e., those each having a heterocyclic ring, with 3 of the carbon atoms in the benzene-like ring replaced by 3 nitrogens). According to a review performed by U.S. EPA (2002a) in response to the mandate set forth in the Food Quality Protection Act of 1996, atrazine, propazine, simazine, and their common chlorinated degradates are compounds in the triazine family determined as sharing a common mechanism of toxicity. That evaluation also led to the completion of a cumulative health risk assessment by U.S. EPA (2006a) for the three triazine pesticides, and to the federal agency's conclusion that the cumulative risks were above the level of concern. That federal regulatory decision was based on the common toxic effects observed earlier in laboratory animals treated with the triazine chemicals (U.S. EPA, 2002b). Those toxic effects found as common included, but were not limited to: attenuation of the luteinizing hormone surge; disruption of estrous cycle; delayed vaginal opening; and mammary tumor formation

(U.S. EPA, 2006a). More details on simazine's adverse health effects can be found in the Reregistration Eligibility Decision (RED) issued by U.S. EPA (2006b) for the herbicide.

In California locally, California Department of Pesticide Regulation (DPR) has prepared a risk characterization document (RCD) for all label uses of simazine in the state. The present pesticide exposure assessment is prepared as an integral part of the RCD. Included in this document (in the Exposure Appraisal section) for comparison purposes is a brief overview of U.S. EPA's exposure assessment given in their RED for simazine.

As in all cases, DPR's RCD for simazine is being prepared in accordance with *California Food and Agricultural Code* (*CFAC)* Sections 11501, 12824-12826, 13121-13135, 14102, and 14103, which collectively and specifically require that the Department must protect individuals and the environment from potential adverse effects that may result from pesticide use in California. As part of the Department's effort in meeting this mandate, pesticide AIs are prioritized for assessment of exposure as well as risk potentials. A fuller description of the pesticide risk prioritization process (and hence that of pesticide exposure as well) can be found on DPR's webpage (http://www.cdpr.ca.gov/docs/risk/raprocess.pdf). Upon the risk prioritization, pesticide AIs are evaluated in accordance with Title 3, *California Code of Regulations (CCR)*, Section 6158. For simazine, the risk prioritization was based in part on its potential risk in drinking water as determined by DPR and in part on developmental delays as well as other adverse health effects in laboratory animals as summarized in the RCD.

II. EXPOSURE-RELATED FACTORS

<u>1. Physical and Chemical Properties</u>

The properties listed in Table 1 below, except the Henry's law constant, were based on those reported in *The Pesticide Manual* edited by Tomlin (2006), *Herbicide Handbook* by the Weed Science Society of America (Ahrens, 1994), or *The Agrochemicals Handbook* edited by Kidd and James (1991). The Henry's law constant was calculated and made available by OEHHA (Fan and Alexeeff, 2001). Simazine has the following chemical structure:

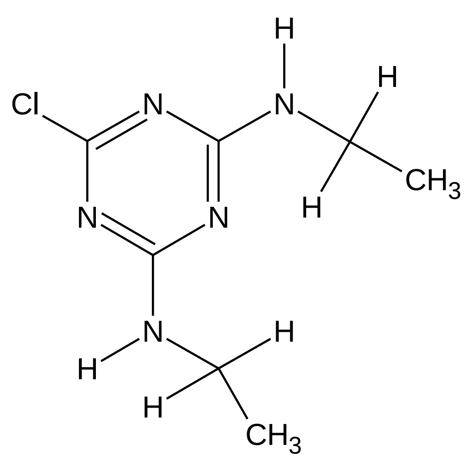

Table 1. Physical and Chemical Properties of Simazine

CAS name	6-choloro-*N*,*N*'-diethyl-1,3-triazine-2,4-diamine
Common name	Simazine
Molecular weight	201.7
Molecular formula	$C_7H_{12}ClN_5$
Physical state	Solid (white crystalline)
Melting point	225-227^o C (decomposition)
Solubility (mg/L)	6.2 in water (20^o C); 570 in ethanol (25^o C)
Specific density	1.302 (20^{o}C)
Partition coefficient	K_{ow} log P = 2.1 (25^o C, *o*ctanol-*w*ater)
Vapor pressure	22.1 x 10^{-9} mmHg (25^o C)
Henry's law constant	3.4 x 10^{-9} atm-m^3/mol (20^o C)

2. Formulations and Label Uses

In addition to the technical grade, a total of 13 herbicide products containing simazine as the AI are actively registered in California as of late April 2013. As noted in Table 2 below, the 13 products include one special local need (SLN: CA-050004; *see* footnote *d* in the table) and three (3) that are almost identical to three others in product label contents except for the California-based EPA registration number. The 13 products are primarily for agricultural uses although, as indicated in footnote *b* in Table 2, some include uses on non-cropped sites such as lawns, rights-of-way, highway medians, and around farm buildings.

Table 2. Simazine Products Actively Registered for Agricultural Use in California as of April 2013[a]

Product	EPA Registration (Reg.) Number
Water-Dispersible Granule	
Princep Caliber 90 Herbicide (Syngenta)	EPA Reg. No. 100-603-ZB, -ZC
Simazine 90DF (Drexel Chemical)	EPA Reg. No. 19713-252-AA[b]
Dry Flowable	
Sim-Trol 9DF (Oxon Italia S.P.A.)	EPA Reg. No. 35915-12-AA[b]
Sim-Trol 90DF (Sipcam Agro USA)	EPA Reg. No. 35915-12-AA-60063[b]
Flowable Concentrate	
Drexel Simazine 4L (Drexel Chemical)	EPA Reg. No. 19713-60-AA[b,c]
Princep 4L (Syngenta)	EPA Reg. No. 100-526-ZD, -ZG, SLN[d]
Princep Liquid (Syngenta)	EPA Reg. No. 100-526-ZE, -ZF
Sim-Trol 4L (Oxon Italia S.P.A.)	EPA Reg. No. 35915-11-AA[b]
Sim-Trol 4L (Sipcam Agro USA)	EPA Reg. No. 35915-11-AA-60063[b]

[a] in parentheses is the name of the manufacturer or distributor; as reflected in the EPA Registration Number column, some products have more than one California-based EPA registration number.

[b] the product includes non-agricultural use.

[c] the product includes application via chemigation.

[d] SLN = special local need (CA-050004) expiring after November 17, 2016; for applying simazine through use of a *micro*sprinkler irrigation system on citrus in the Fresno and Tulare counties.

For the simazine products listed in Table 2, aerial and ground applications are allowed where applicable. In addition, the Drexel flowable concentrate and the SLN allow application via chemigation and microsprinkler irrigation, respectively. Ground application may be carried out either using handheld sprayers, as in nurseries and for spot treatment around fruit and nut trees, or using groundboom sprayers for wider areas between trees and for side dressing on fruit and nut crop floors. All aerial and ground applications of simazine are restricted to prevent any contamination of groundwater or any damage to crops. The maximum rates for the various sites for all active labels are 5 lb AI/acre or lower.

3. Label Precautions

The 13 simazine products listed in Table 2 are all classified as having Category III toxicity (with the signal word CAUTION). The following restrictions are specified on their product labels where applicable: (1) Do not apply the herbicide when wind speed favors drift beyond the areas intended for treatment; (2) only protected handlers may be in the area during application; and (3) use aerial application only where specified in the use directions.

The product labels all require applicators and other handlers to wear normal work clothes (i.e., long pants, a long-sleeved shirt, and shoes plus socks) and chemical-resistant gloves. Mixer/loaders handling dry flowable or water-dispersible granules additionally must wear coveralls and a chemical-resistant apron over normal work clothes and a NIOSH-approved dust/mist filtering respirator. Coveralls, shoes plus socks, and chemical-resistant gloves are required for early entry that involves contact with anything that has been treated, such as plants, soil, or water. The REI (restricted entry interval) is 12 hours post-application, which is not task-specific. The concern whether or not simazine is a skin sensitizer is not mentioned on any of the product labels registered in California (as of late April 2013).

4. California Requirements

According to Title 3, *CCR*, Section 6738(b), goggles, face shield, or any safety glasses that may provide front and supplemental brow and temple protection, are required for California workers handling pesticides in the field. There appear to be no other worker or health safety requirements in California for handlers working with simazine, that may have an impact on the exposure assessment.

5. Usage in California

Table 3 ranks the sites/crops on which simazine was applied during 2006 through 2010 (the latest available year, as of late April 2013). The ranking was based on the total amount of the AI applied at each site during the five-year interval. These pesticide use data were extracted from the annual Pesticide Use Reports (PUR) published by DPR (2013). The table shows that nearly 90% of the simazine use has been on soil where tree/vine crops (e.g., almonds, avocados, grapes, oranges, walnuts) are planted or will be planted. Table 3 also shows that the use of simazine in *others*, such as in nurseries, collectively amounted to less than 1.5%.

6. Illness Summary

The Pesticide Illness Surveillance Program (PISP) at WHS maintains a database of pesticide-related illnesses and injuries occurring in California. These illness data, which are received through incidents investigations, medical reports from physicians, or workers' compensation records, are logged into the database by the PISP scientists where these data can be used later for future assessments of worker protection standards and for evaluation of illness trends.

Table 3. Ranking for All Reported Uses of Simazine in California, 2006-2010[a]

Commodity/Site	*Pounds AI Applied*	*Percentage*
Orange (all or unspecified)	738,995.7	30.6
Grapes, wine	458,993.2	19.0
Grapes (all except wine)	340,554.9	14.1
Almonds	213,601.9	8.9
Walnuts (English, Persian)	192,048.1	8.0
Rights-of-Way	186,236.0	7.7
Avocados (all or unspecified)	60,521.9	2.5
Lemons	50,675.2	2.1
Olives (all or unspecified)	47,627.2	2.0
Landscape Maintenance	41,500.5	1.7
Peaches	20,463.1	0.9
Grapefruits	18,562.7	0.8
Nectarines	11,440.5	0.5
Others	*33,314.7*	*1.4*
Total (all commodities in the 5-year period)	2,414,532.6	100.0

[a] usage of the simazine active ingredient (AI) is based on the annual Pesticide Use Reports published by the California Department of Pesticide Regulation (DPR, 2013).

The database, which is now accessible at the DPR website (http://apps.cdpr.ca.gov/calpiq/), showed that between the latest available years 2006 through 2010, a total of 1 illness was reported to PISP as probably related to simazine use in combination with other pesticides. The case involved a mixer/loader (from use in a vineyard in 2006) experiencing eye irritation as the only symptom. No days of disability or hospitalization were recorded for this case.

7. Major Categories of Potential Exposure Scenarios

The potential exposure scenarios for simazine considered in this assessment were all derived from the comprehensive list included in the scoping proposal (as summarized in Appendix A). To facilitate the discussion, all 14 scenarios in that list were subsumed here under eight (8) major, broader exposure scenario categories as follows: (1) mixing/loading for aerial spray; (2) mixing/loading for groundboom spray; (3) mixing/loading for chemigation or microsprinkler irrigation; (4) spraying with aerial equipment; (5) spraying with groundboom equipment; (6) flagging for aerial spray; (7) mixing/loading *and* application (henceforth M/L/A or M/L/application) with handheld equipment; and (8) nonusers as well as bystanders.

Handheld equipment for M/L/A may include the following three main types of handwand or handgun controlled sprayers commonly used for spraying liquid formulations to target areas: (1) low-pressure handheld sprayers (including plastic bottle type sprayers, primarily for small or spot areas); (2) backpack sprayers (primarily for hard-to-reach or relatively larger areas); and (3) occasionally high-pressure handwand sprayers (mainly for larger areas).

In the present exposure assessment, bystander or nonuser residential exposure to simazine was limited to oral intakes and dermal uptakes of soil and turf residues by young children in play areas. This type of residential exposure represents the worst case for all age groups. Exposure to drift in the residential area is not anticipated since simazine is supposed to be watered into the soil following application (which is not allowed when wind speed favors drift beyond the areas intended for treatment). As elaborated and substantiated later on, inhalation for bystanders (including nonuser residents) was considered negligible.

The following observations and considerations justify why *reentry* exposures to simazine are also deemed negligible and were thereby not assessed quantitatively for fieldworkers or lawn care specialists. As with all other herbicides, simazine is supposed to be used with care to avoid crop injury; and no application is allowed in fields where crops reach the harvest stage. The labels specify that turfgrass for sod is not to be treated if it is to be cut or lifted within 30 days. The herbicide also may not be used on golf greens. Its mode of herbicidal action relies on its absorption into the roots of weed seedlings. Therefore, it is often a common as well a good practice to remove the prunings and trash in the field before any spraying is to take place. Although workers may enter a field to irrigate or to scout a treated area, their dermal contact from such reentry activities is expected to be minimal in that the herbicide residues are primarily in the soil, or at most on weed or contaminated turfgrass not taller than ankle high. Although in some cases the herbicide may be applied before weeds exceed 1.5 inches, most of the product labels specify that the application be made prior to weed emergence or after removal of weed growth. Reentry exposure from mowing was considered negligible due to the limited dermal contact with treated turfgrass (as further discussed in Subsection V-3). Given that simazine has a very low vapor pressure (Table 1), inhalation exposure to its air-borne residues from reentry activities is also expected to be minimal.

III. ACUTE TOXICITY AND PHARMACOKINETICS

1. Acute Toxicity and Dermal Sensitization

Table 4 summarizes the acute toxicities of simazine conducted in laboratory animals. Much of these toxicity data were found similar or identical to those reviewed and summarized by OEHHA (Fan and Alexeeff, 2001).

2. Dermal and Inhalation Absorption

Human studies on dermal absorption of simazine were not available for review by WHS. A daily absorption rate of 6% of *atrazine* dose observed in humans, however, was used by U.S. EPA (2003, 2006b) in its Interim Reregistration Eligibility Decision (IRED) for atrazine and its RED for simazine. The present exposure assessment supported that decision and thereby used the same daily rate as a surrogate to calculate the absorbed dermal doses of simazine.

U.S. EPA's determination was based on a dermal adsorption as well as a metabolism study in which 10 human subjects were exposed to a single topical dose of atrazine for 24 hours (Hui *et al*., 1996). The 10 volunteers (ages 43 to 74 years) were divided into two dose groups, with each volunteer's ventral forearm being dosed with ^{14}C-atrazine in a 25-cm^2 area. The higher daily dermal absorption rate of 6% was observed in the lower dose group consisting of 6 volunteers. U.S. EPA also employed this higher rate on atrazine as a surrogate for simazine, pointing out that the two chemicals are very similar in structure and functions. In addition to such similarities, the *in vivo* dermal absorption rates for both chemicals observed in rats (as briefly described below) were found highly comparable. These observations all lent to the strong support that the absorption rates for both chemicals *in humans* are likely similar.

Table 4. Summary of Acute Toxicity Data for Simazine Technical

Species	Effect Level	Test Method	References[a]
Rat	LD_{50} > 5,000 mg/kg	Single oral dose	Ahrens; K & J; S & S
Mouse	LD_{50} > 5,000 mg/kg	Single oral dose	K & J
Rabbit	LD_{50} > 10,000 mg/kg	Single dermal dose	K & J; S & S
Rabbit	LD_{50} > 3,100 mg/kg	Single dermal dose	Ahrens; K & J; S & S
Rat	LC_{50} > 2.5 mg/L	Inhalation, 4 hours	Ahrens; S & S
Rabbit	non-irritant	Primary skin irritation	Ahrens; K & J; S & S
Rabbit	non-irritant, slight	Primary eye irritation	Ahrens; K & J; S & S
Guinea pig	slight, *not* a sensitizer	Skin sensitization	Ahrens; Kuhn; S & S

[a] Ahrens = Ahrens (1994); K & J = Kidd and James (1991); Kuhn = Kuhn (1989); S & S = Stevens and Sumner (1991).

An *in vivo* percutaneous absorption study (Murphy *et al*., 1988) was submitted in which a simulated 4L formulation of ^{14}C-simazine was applied to the back of 32 young male albino rats each weighing 200 to 300 grams. That *in vivo* study was reviewed by Dong (1989), who concluded that a daily absorption rate of 18.7% should be sufficient and appropriate for use to calculate the dermal absorbed doses of simazine in animals (particularly rats). That absorption rate was derived from the low dose treatment for 10 hours and was based on the inclusion of a large amount of residues remaining in the rat skin. As common practice at WHS, residues bound to skin are currently treated as potentially (and completely) absorbed.

In another *in vivo* study (Chengelis, 1994), the maximum amount of ^{14}C-*atrazine* absorbed was also found as around 20% after the low dose group of healthy male rats (Charles River CD) was exposed for 10 hours. The ^{14}C-atrazine used in that rat study was also in a simulated 4L formulation. In essence, the dermal absorption of simazine in *humans*, if and when made available, is expected to be comparable to that (6%) observed for atrazine in humans. Such an expectation is once again based on the observations that the two chemicals are very similar in structure and functions, and that the results from the two *in vivo* dermal absorption studies on the two chemicals in rats were comparable.

There were no animal or human inhalation absorption data available to WHS for simazine. The present exposure assessment thereby used the current interim default value of 100% (Frank, 2008) for both the inhalation uptake and the inhalation intake (absorption) in calculating the inhalation doses of simazine where necessary.

3. Animal and Human Metabolism

Pharmacokinetics studies apparently had not been conducted by the registrants or available in the open literature concerning the metabolic fate (i.e., the biotransformation) of simazine in humans, since no studies of this type were submitted by the registrants. Nonetheless, Ciba-Geigy did perform a preliminary investigation into the metabolism of simazine in rats (Simoneaux and Shy, 1971). In that (apparently never further finalized) study, which was reviewed by OEHHA (Fan and Alexeeff, 2001), white female rats were administered a single oral dose of 0.5 mg/kg of ^{14}C-ring labeled simazine. Metabolites in 24-hour urine samples were analyzed by thin-layer chromatography and electrophoresis. The major metabolites found in the urine were 2-hydroxy-4,6-diamino-*s*-triazine, 2-hydroxy-4-amino-6-ethylamino-*s*-triazine, and hydroxy-simazine. The three metabolites accounted for 6.8, 6.1, and 14.0% of the radioactivity recovered in the urine, respectively. In that preliminary study, about 50% of the radioactivity in the urine was not identified for metabolites.

OEHHA also reviewed a study (Bradway and Moseman, 1982) later available in the open literature, in which male Charles River CD rats were dosed with 1.0 mL of peanut oil per day by gavage for 3 consecutive days. The 1.0 mL oil vehicle contained 0.005, 0.05, 0.5, 5.0, or 50 mg simazine as the test dose (yielding a dosage of 0.017, 0.17, 1.7, 17, or 170 mg/kg/day, respectively). Urine samples were collected over a 24-hour interval and analyzed by gas chromatography for the presence of *N*-dealkylated metabolites. The results from that rat study suggested that the di-*N*-dealkylated metabolite was the major degradate, ranging from 1.6% of the dose at 0.5 mg/mL applied for 3 days to 18% of the dose at 5.0 mg/mL also applied for 3 days. (Note that the dose of 50 mg/mL was not used in the part of the study that measured the di-*N*-dealkylated degradate.) Those metabolism data tended to support that the rate of metabolism for simazine, though low, may be dose-dependent.

IV. ENVIRONMENTAL CONCENTRATIONS

1. Ambient and Onsite Air

In early 1998, Cal/EPA's Air Resources Board (ARB, 1999) conducted a field study in which concentrations of simazine in ambient air were monitored in Fresno County in an effort to coincide with the herbicide's relatively high use in grape vineyards in that county. As part of the same study, ARB later in that year (in December) also monitored the onsite air levels (henceforth also referred to as 'application concentrations', to be consistent with ARB's term usage) around an orange orchard in Tulare County, where 20 acres of the soil were sprayed with simazine just prior to air monitoring.

The ambient air monitoring phase was conducted during a six-week period from February 18 to April 1, 1998. In addition to ARB's ambient air monitoring station in downtown Fresno for collection of background samples, four sampling sites were used to represent areas of the county where grape farming was (and still is) predominant and in populated areas or in areas frequented by people. The four sampling sites consisted of: two high schools; one middle school; and one elementary school. One (approximately) 24-hour sample from each of the five sites was collected each week (between Monday through Friday) at a flow rate of 3 L/min, for a total of 24 days. This ARB sampling scheme thereby resulted in a total of 120 (=

24 samples/site x 5 sites) ambient air samples, in addition to the 30 collocated samples and 15 quality assurance spikes collected during the six-week monitoring period.

Of the 120 ambient air samples collected, 21 were found above the estimated quantitation limit (EQL) of 18.2 ng/sample, or nearly 5 times the method detection limit (3.8 ng/sample). The highest simazine concentration after adjustment for field recovery (84%) was reportedly 18 ng/m^3. As described in Subsection V-3.D, these ambient and application air data were all used to assess the inhalation exposure potential for bystanders.

The onsite air samples from Tulare County were collected at 8 time points following spray application through approximately 3 days. The application was conducted on December 19, 1998 at the rate of 3.6 lb AI per acre via two groundboom spray rigs. Four air samplers were positioned onsite, with one on each side of the 20-acre orchard and a fifth sampler collocated at the south position. The four air samplers were located about 20 to 50 feet from the orange orchard at the same elevation as the field except the one on the east, which was 5 feet higher.

Of the 32 onsite samples collected (excluding the spikes, blanks, and collocated samples), 6 were found above the EQL. The highest simazine concentration after adjustment by ARB for field recovery (104%) was reportedly 190 ng/m^3, which was from one of the four one-hour samples collected during the second sampling period (i.e., during the first hour immediately following application, as the first sampling period was used for collection of background samples). All four background samples had air concentrations above the EQL for simazine, with an average of 6.9 ng/m^3.

2. Dislodgeable Foliar Residues

Significant levels of simazine's dislodgeable foliar residues (DFR) on crops or non-target sites are not anticipated, given that simazine is primarily a pre-plant or pre-emergence herbicide to be applied to the soil followed by watering in. As common practice, the herbicide should not be applied directly or very close to crops as it would damage their yield. Accordingly, the DFR level on any crop at any time, if any, is expected to be negligible.

3. Turf and Other Surface Residues

Other types of surface residues, such as those on sod-farms or golf course turfgrass, generally are not considered to be the same type of dislodgeable residues as those present on the foliage of the more common agricultural commodities. In 1999, Novartis Crop Protection conducted a simulation study to measure the magnitude as well as the dissipation behavior of simazine residues on turfgrass that were considered to be transferable to human skin or clothing and were also intended as the surrogates for atrazine (Rosenheck, 1999). These data on turfgrass residues, herein referred to as *transferable turf residues* (TTR), were submitted by the registrants in their response to U.S. EPA's data call-in for the reregistrations of atrazine and of simazine used on lawns and turf.

The trials in the atrazine TTR study were conducted in two locations, with one in Florida and the other in California. These two sites each consisted of two plots, with one plot irrigated and the other not. The target application rate for each plot was the maximum label rate of 2.0 lb AI/acre applied as a liquid broadcast spray to turfgrass. The Modified California Roller technique developed by the Outdoor Residential Exposure Task Force (ORETF) was used to *pick up* the 'transferable' turf residues. Four replicate samples were collected at each site at various time points through 35 days post-application. The field recoveries averaged 84.2 and 82.5% for samples collected at the Florida and California sites, respectively.

As expected, the TTR on the irrigated turf were lower, by about two- to three-fold when compared to those on turf not irrigated. The average half-life of those turf residues was 12.3 days, irrespective of irrigation scheme. The average initial deposition, normalized to the spray rate, was 0.12 $\mu g/cm^2$ per lb AI/acre sprayed for the non-irrigated turf, and 0.05 $\mu g/cm^2$ per lb AI/acre for the irrigated turf. The TTR from the non-irrigated and the irrigated plots represented 1.0 and 0.47% of the spray rate, respectively.

Note that the above TTR data, as further considered in Subsection V-3.B, must be treated with care and caution, considering that the roller method used to collect and measure TTR type samples has not been fully standardized or officially accepted by regulatory agencies. In this type of sample collection, both the weight of the roller used and the force exerted to the roller are critical to the amount of residues to be captured. In fact, available field data (Welsh *et al*., 2005) showed that the TTR values obtained from the Modified California Roller method on average could be two to three times higher than those from a specific variation when comparing the TTR samples side by side. That comparison study also reported that several variations of the roller method exist today.

4. Offsite Soil Residues

All product labels for agricultural use allow simazine to be broadcast sprayed to soil or weeds at up to 5 lb AI/acre, depending on the crop or soil type involved. Levels of the onsite soil residues further depend on time since application and on depth of soil sampled, although in this case the theoretical maximum from *a single* application is unlikely to exceed 22.5 mg/kg, or 22.5 ppm (parts per million). This maximum soil level was estimated using the default of 2.0 g/cm^3 assumed as the specific density of soil, and the practical thinnest soil layer of 1.27 cm (= 0.5 inch). That is, 22.5 mg/kg (maximum soil level) = (5.0 lb AI, maximum label rate)/[acre x 1.27 cm soil depth] = 2.3 kg/[4.05 x 10^7 cm^2 x 1.27 cm] = 2.3 kg/[5.1 x 10^7 cm^3] = 2.3 mg/[5.1 x 10 cm^3] = 2.3 mg/[(51 x cm^3) x (2.0 g/cm^3, as the specific density of soil)].

While the simazine levels in *offsite* soil are expected to be much lower than the theoretical maximum (i.e., 22.5 mg/kg) calculated above, actual data on this type of soil levels in California are very limited. In the study conducted in California's northern Central Valley (Powell *et al*., 1996), which appears to be the only one of this kind available today, simazine was *not* detected in any of the samples for soil sample <0.3 m depth. The maximum soil level of simazine found in that study prior to herbicide application was 0.7 mg/kg.

5. Ambient Water

From a regulatory standpoint, surface and ground (well) water concentrations of simazine in California are expected to be below the national Maximum Contaminant Level (MCL) of 4 μg/L (U.S. EPA, 2009), which is the same as the California public health goal set for simazine (Fan and Alexeeff, 2001). This was indeed the case, at least around the early 2000s when the environmental fate of simazine was investigated rather intensively by DPR's

Environmental Monitoring Branch. According to a report given by that branch (Gunasekara, 2004), the surface and ground (well) water levels of simazine were extensively monitored in California from 2000 to 2002 and from 2001 to 2003, respectively. Between 147 and 460 sites were monitored in each of the three years for surface water levels, whereas for ground water over a thousand sites were monitored in each of the three years. The highest level observed in those monitoring years was 3.7 µg/L, detected at one of the surface water sites. As further substantiated in the Exposure Appraisal section, these ambient levels are not likely to pose any significant exposure to simazine for Californians swimming in surface water.

V. EXPOSURE ASSESSMENT

In an effort to facilitate the exposure assessment discussion presented here, the eight (8) major groups of use/exposure scenarios identified in Subsection II-7, which again were based on the comprehensive list presented in Appendix A, were further subsumed under three even broader categories: (1) handler exposure from working with simazine in an agricultural setting; (2) occupational or non-occupational exposure of users handling simazine in a *non*-agricultural setting; and (3) exposure for bystanders as well as nonuser residents, as from oral intake and dermal uptake of soil and turf residues by children playing on a treated lawn.

Field reentry exposures to simazine were considered insignificant, as justified in Subsection II-7. Again, as it may be worth repeating here, simazine is to be used with care to avoid crop injury; and no spray is allowed in fields where crops reach the harvest stage. For example, turfgrass for sod is not to be treated if it is to be cut or lifted within 30 days. Although workers may enter the field to scout or irrigate a treated area, their dermal contact with residues in the field is minimal, as the residues are primarily in the soil or at most on weeds below ankle height. Given that simazine has a very low vapor pressure of 22.1 x 10^{-9} mmHg at 25^{o} C (Table 1), inhalation exposure to its airborne residues from field reentry was also expected to be negligible, especially when the reentry *could* take place long after application.

1. Handler Exposure from Agricultural Use

The dermal and inhalation exposure rates used in the assessment are summarized in Tables 5 through 8, respectively, for applicators, human flaggers, mixer/loaders, and M/L/applicators handling various liquid formulations of simazine available for agricultural use. Data on the exposure rates and the basic assumptions used in the calculations are footnoted in those tables. Below are further elaborations on those data and assumptions that were considered to be more crucial or less trivial.

A. Daily Acreages and Application Rates

Maximum application rates for the various liquid formulations and spray methods used are listed in Tables 5 through 8, with the highest maximum rate being 5.0 lb AI/acre. In this exposure assessment, the maximum daily acreages were conservatively assumed to be 600 and 100 for aerial and groundboom sprays, respectively, by a single crew. The estimates for maximum acreages used in the present exposure assessment, while consistent with those used by WHS earlier (e.g., Meinders and Krieger, 1988; Dong and Haskell, 2000), were about half of the default acreages used by U.S. EPA (2001a) for the following reasons.

Table 5. Data and Assumptions Used for Estimation of Simazine Dosage for Applicators from Agricultural Use

Application and Formulation	Median[a] Numbers	Exposure (μg/lb AI handled)[b]			Acres[c] per Day	Rate[d] (lb AI/acre)	Absorbed Daily Dosage (ADD, μg/kg BW/day)[e]			
		Dermal	Hand	Inhalation			Dermal	Hand	Inhalation	Total
Liquid										
aerial[f]	10, 9, 14	52.2	9.6	0.57	600	5	134.2	24.6	24.4	183.3
groundboom[g]	33, 29, 22	20.9	45.6	1.2	100	5	9.0	19.5	8.6	37.1

[a] median numbers of observations for dermal, hand, and inhalation, respectively, in the Pesticide Handler Exposure Database (PHED, 1995) subset used.

[b] appropriate personal protective equipment was used as per label specifications (i.e., gloves, long pants, long sleeves, no respirator); dermal = total dermal – hand.

[c] default maximum acres/day, as discussed in the text (Subsection V-1.A: *Daily Acreages and Application Rates*).

[d] maximum label rate, as discussed in the text (Subsection V-1.A: *Daily Acreages and Application Rates*).

[e] total absorbed dosage (μg/kg/day) = [(dermal + hand + inhalation) absorbed dosage] = [{(dermal plus hand exposure rate) x (6% dermal absorption, *see* Subsection III-2) + (inhalation exposure rate) x (100% default inhalation absorption, *see* Subsection III-2)} x {(application rate) x (acres/day) x (70 kg default body weight, Thongsinthusak *et al.*, 1993a and U.S. EPA, 1997)$^{-1}$}].

[f] PHED subset presented in Appendix B-1.

[g] PHED subset presented in Appendix B-2.

Table 6. Data and Assumptions Used for Estimation of Simazine Dosage for Aerial Human Flaggers from Agricultural Use

Application and Formulation	Median[a] Numbers	Exposure (μg/lb AI handled)[b]			Acres[c] per Day	Rate[d] (lb AI/acre)	Absorbed Daily Dosage (ADD, μg/kg BW/day)[e]			
		Dermal	Hand	Inhalation			Dermal	Hand	Inhalation	Total
Liquid & aerial[f]	26, 30, 28	37.4	0.6	0.20	600	5	96.2	1.5	8.6	106.3

[a] median numbers of observations for dermal, hand, and inhalation, respectively, in the Pesticide Handler Exposure Database (PHED, 1995) subset used.

[b] appropriate personal protective equipment was used as per label specifications (i.e., long pants, long sleeves, no respirator, no gloves); dermal = total dermal – hand.

[c] default maximum acres/day, as discussed in the text (Subsection V-1.A: *Daily Acreages and Application Rates*).

[d] maximum label rate, as discussed in the text (Subsection V-1.A: *Daily Acreages and Application Rates*).

[e] total absorbed dosage (μg/kg/day) = [(dermal + hand + inhalation) absorbed dosage] = [{(dermal plus hand exposure rate) x (6% dermal absorption, *see* Subsection III-2) + (inhalation exposure rate) x (100% default inhalation absorption, *see* Subsection III-2)} x {(application rate) x (acres/day) x (70 kg default body weight, Thongsinthusak *et al.*, 1993a and U.S. EPA, 1997)$^{-1}$}].

[f] PHED subset presented in Appendix B-3.

Table 7. Data and Assumptions Used for Estimation of Simazine Dosage for Mixer/Loaders from Agricultural Use

Application and Formulation	Median[a] Numbers	Exposure (μg/lb AI handled)[b]			Acres[c] per Day	Rate[d] (lb AI/acre)	Absorbed Daily Dosage (ADD, μg/kg BW/day)[e]			
		Dermal	Hand	Inhalation			Dermal	Hand	Inhalation	Total
Flowable[f]										
aerial	90, 59, 85	433.0	58.2	2.4	600	5	1,113.4	149.7	102.9	1,365.9
groundboom	90, 59, 85	433.0	58.2	2.4	100	5	185.6	24.9	17.1	227.7
chemigation[g]	90, 59, 85	433.0	58.2	2.4	300	4	445.4	59.8	41.1	546.4
Dry Flowable[h]										
aerial	23, 21, 23	193.0	9.7	0.7	600	5	496.3	24.9	30.0	551.2
groundboom	23, 21, 23	193.0	9.7	0.7	100	5	82.7	4.2	5.0	91.9

[a] median numbers of observations for dermal, hand, and inhalation, respectively, in the Pesticide Handler Exposure Database (PHED, 1995) subset used.

[b] appropriate personal protective equipment was used as per label specifications (i.e., gloves, long pants, long sleeves, no respirator, *see* Section VI-6 for exceptions); dermal = total dermal – hand.

[c] default maximum acres/day, as discussed in the text (Subsection V-1.A: *Daily Acreages and Application Rates*).

[d] maximum label rate, as discussed in the text (Subsection V-1.A: *Daily Acreages and Application Rates*).

[e] total absorbed dosage (μg/kg/day) = [(dermal + hand + inhalation) absorbed dosage] = [{(dermal plus hand exposure rate) x (6% dermal absorption, *see* Subsection III-2) + (inhalation exposure rate) x (100% default inhalation absorption, *see* Subsection III-2)} x {(application rate) x (acres/day) x (70 kg default body weight, Thongsinthusak *et al.*, 1993a and U.S. EPA, 1997)$^{-1}$}].

[f] PHED subset presented in Appendix B-4.

[g] including microsprinkler irrigation.

[h] PHED subset presented in Appendix B-5; including water-dispersible granule.

Table 8. Data and Assumptions Used for Estimation of Simazine Dosage for Mixer/Loader/Applicators from Agricultural Use

Application and Formulation	Median[a] Numbers	Exposure (µg/lb AI handled)[b]			Acres[c] per Day	Rate[d] (lb AI/acre)	Absorbed Daily Dosage (ADD, µg/kg BW/day)[e]			
		Dermal	Hand	Inhalation			Dermal	Hand	Inhalation	Total
Flowable										
low-pressure[f]	15, 15, 15	1,078	36.4	41.3	1	5	4.6	0.16	3.0	7.7
high-pressure[g]	13, 13, 13	6,580	339.0	151.0	5	5	141.0	7.3	53.9	202.2
backpack[h]	11, 11, 11	22,300	9.7	17.5	1	5	95.6	0.04	1.3	96.9

[a] median numbers of observations for dermal, hand, and inhalation, respectively, either in the Pesticide Handler Exposure Database (PHED, 1995) subset used or in the exposure monitoring study cited in footnote *f* below.

[b] appropriate personal protective equipment was applied as per label specifications (i.e., gloves, long pants, long sleeves, no respirator); dermal = total dermal – hand.

[c] default maximum acres/day, as discussed in the text (Subsection V-1.A: *Daily Acreages and Application Rates*).

[d] maximum label rate, as discussed in the text (Subsection V-1.A: *Daily Acreages and Application Rates*).

[e] total absorbed dosage (µg/kg/day) = [(dermal + hand + inhalation) absorbed dosage] = [{(dermal + hand exposure rate) x (6% dermal absorption, *see* Subsection III-2) + (inhalation exposure rate) x (100% default inhalation uptake, *see* Subsection III-2)} x {(application rate) x (acres/day) x (70 kg default body weight, Thongsinthusak *et al.*, 1993a and U.S. EPA, 1997)$^{-1}$}].

[f] from Klonne *et al.* (1999b) on DCPA (dimethyl tetrachloroterephthalate) as presented in Table 11 in this document, after normalization to a default body weight of 70 kg; note that no adjustment was made for the respiration rate as that study used the same default rate of 16.7 L/m (actually reportedly 17 L/m); taking the average of all formulations used (flowable, water dispersible granules, and wettable powder) while using the handgun data by Rosenheck *et al.* (1993) on atrazine (as presented in Table 10 in this document) for cross-reference; handgun was considered as operating in low pressure (as a worst-case).

[g] PHED subset presented in Appendix B-6.

[h] PHED subset in presented Appendix B-7.

For maximum daily acreage used in pesticide exposure assessment, the current interim guidance at WHS is to use the standard values set forth in a U.S. EPA (2001a) policy except when there are more relevant data to the contrary. In fact, even the federal policy explicitly advises that "(*These default) values should be modified by pesticide- and crop-specific knowledge that affects the number of acres that can be treated in a day (e.g., high number of gallons required per acre, specific geographic or cultural practice crop restrictions)*." In the case with simazine considered here, the daily default of 1,200 acres set forth in the U.S. EPA policy was deemed unrealistically high even for high-acre crops (e.g., cotton, corn).

Previously WHS scientists (e.g., Meinders and Krieger, 1988) adopted the default of 600 acres in part because of the observation made in yet another earlier study by WHS (Peoples *et al.*, 1981). That earlier study reported that while the two firms under study each claimed to have treated on average 1,000 acres per day, in all confirmed cases they each actually had *two* pilots working each day for up to 7 hours from 5 AM to noon, thereby yielding reportedly a total of 6 to 12 actual hours of spraying each day by *all* (i.e., *two*) pilots in *each firm*.

Another reason why the earlier WHS default continued to be used here with simazine is that, to a great extent, the PUR data (DPR, 2013) for the 10 most recent available years (2001 through 2010) also supported the use of 600 acres or less as a conservative maximum default for aerial spray of simazine. When the PUR data were further extracted by aerial application of simazine grower ID, application date, and application use number, the *highest* acreage treated per aerial application (as per use number) in each year was found to be 640 or lower for the 10 years (2001 through 2010), with an average of 362 acres for the 10 yearly highest (330, 640, 640, 640, 114, 70, 80, 225, 361, and 520 acres, respectively).

Note that one of the output columns available in the California Pesticide Information Portal (DPR, 2013) is *sequential* use number (coded as Use_Number), which is used to uniquely identify all records associated with a single application of a product and hence by definition is date- and grower- or even applicator-specific. Although growers each can have aerial applications done to two (or more) fields nearby on the same day, it is unlikely for them to use two different use numbers for two (or more) fields (close to each other) treated on the same day as if they should be treated separately not under a single large operation, especially if the two applications were to be performed by the same pilot. A closer look at the PUR data also indicated that each year only a very few application use numbers from the same day appeared in consecutive order. That is, this last finding alone suggested that only a very few pilots, if any at all, had each made multiple aerial applications on the same day.

U.S. EPA (2001a) uses 80 and 200 acres per day as the defaults for groundboom spray to low- and high-acre crops, respectively. In the present exposure assessment, the maximum daily acreage for ground spray was assumed to be 100, for some of the reasons given above. Further argument was given in the Exposure Appraisal section for using 600 and 100 acres as the daily defaults for aerial and non-handheld ground applications, respectively.

In the present exposure assessment, the maximum daily acreage for chemigation, including microsprinkler irrigation, was assumed to be in-between those for ground and aerial sprays. Accordingly, a daily default of 300 acres was used for chemigation. U.S. EPA's daily default of 350 acres was based on an average crop circle of ~120 acres, with 3 circles being treated per day. The default used here was also based on 3 circles, but with each circle of 100 acres (more or less per default for groundboom spray).

For M/L/applicators using the various types of handheld sprayers, the defaults used as maximum daily acreages were largely comparable to those used by U.S. EPA (2001a). The defaults used in the present exposure assessment were 5 acres for high-pressure handgun, and 1 acre for low-pressure handgun and backpack type. U.S. EPA (2001a) uses 40 and 1,000 *gallons* of spray solution per day as the defaults for backpack sprayers and for handgun type, respectively. After unit conversion and adjustment for time spent per workday, the defaults used in the present exposure assessment for M/L/applicators were deemed comparable to those adopted by U.S. EPA (2001a). As noted in Subsection V-1.F, the M/L/A scenarios as listed in Table 8 were more for handlers in the *non*-agricultural setting. They were included here for handlers in the agricultural setting primarily for completeness. More specifically, there is a greater potential for a M/L/applicator to apply a herbicide to turf in a non-farm area than to larger farm or field areas where crops grow or will grow.

The maximum spray rates are 5.0 lb AI per acre or lower for all simazine product labels (*see* further discussion in Section VI-6). In particular, the maximum rate is 2.0 lb AI/acre for turf-grass. It is important to note that, in areas where crops are grown or to be grown shortly, *band* applications are either considered necessary or preferred over ground or aerial broadcast.

B. Data on Exposure Rates.

No chemical-specific data were found available for exposures involving specifically the use of simazine. And as elaborated on later in this subsection, the available exposure monitoring data on atrazine were found scientifically unsound as surrogates for simazine. Therefore, for the handler groups considered here (i.e., for those included in Tables 5 through 8), the dermal and inhalation exposure rates were necessarily relied on the nonchemical-specific Pesticide Handler Exposure Database (PHED, 1995) or the exposure data on other herbicides. It is of note that by all standards, atrazine is supposed to be a highly suitable surrogate for simazine because both chemicals share many physicochemical properties in common and because their uses as a herbicide are very similar. Furthermore, these two members of the *s*-triazine family were concluded by U.S. EPA (2002b) to share a common mechanism of toxicity.

Specifically, for all but one of the handler scenarios included in this exposure assessment, the dermal and inhalation exposure rates were based on the arithmetic means derived from the PHED surrogate subsets appended to this document (as Appendices B-1 through B-7). Note that for consistency and transparency purposes, all the exposure rates derived from these and other (commonly-used) PHED subsets have been standardized in a WHS technical report (Beauvais *et al.*, 2008). As footnoted in Table 8, the one exception was for M/L/applicators using low-pressure handheld sprayers, for which the available exposure data on DCPA (dimethyl tetrachloroterephthalate) were used instead as the last resort. Even though DCPA is also a herbicide, it is not similar to simazine in structure or in mode of action.

(1) PHED Data. PHED (1995) was developed by U.S. EPA, Health Canada, and American Crop Protection Association to provide nonchemical-specific pesticide handler exposure

estimates for specific handler scenarios. It combines handler exposure data from multiple field monitoring studies of different pesticides. The user (assessor) is supposed to select a subset of the data having the same or a similar application method and formulation type as those in the target exposure scenario. The use of nonchemical-specific exposure estimates is based largely on the following two assumptions (Versar, 1992) that: (a) handler exposure is primarily a function of formulation type and pesticide application method or equipment, and not much of the physical or chemical properties of the specific AI involved; and (b) handler exposure is proportional to the amount of AI handled, at least within a practical range (*see* the Exposure Appraisal section for further discussion concerning this latter part of the assertion or assumption).

When using surrogate data to estimate acute or short-term exposure (up to 7 days), WHS uses the 90% upper confidence limit (UCL) on the 95th percentile calculated. The confidence limit is used to account for some of the uncertainties inherent in using surrogate data and to increase the confidence in the estimate used. Confidence limits on percentiles, also called tolerance limits, are described by Hahn and Meeker (1991). Estimating the confidence limit requires knowing the mean and standard deviation. PHED calculates and reports the mean of total dermal exposure, but only the coefficients of variation (CV) for separate body regions. Because the sample sizes per body region differ and because the correlations among body regions are unknown, the standard deviation of total dermal exposure cannot be calculated from these body region-specific CV.

In order to approximate the upper (and lower) confidence limits for the 95th percentile, WHS makes the assumption that total dermal exposure is lognormally distributed across persons and has a CV of 100 percent. The method of approximation is described in Frank (2007) and uses the concept that in any lognormal distribution with a given CV, the UCL for a percentile is a constant multiple of the arithmetic mean. The value of the multiplier then depends only on sample size (i.e., number of replicates or observations). To use the approximation with PHED data, the multipliers corresponding to the median sample sizes over the major specific body regions (i.e., hand, inhalation, and rest of body) are used. For example, if the median sample size for hand is between 20 and 119, the multiplier is 4; if the sample size is between 12 and 19, the multiplier is 5. The median sample sizes used for the three major body regions are listed in the tables presented in this section (i.e., Tables 5 through 8), where appropriate. The actual numbers of observations for the various body regions are given in the PHED reports appended to this document (as Appendices B-1 through B-7).

When using surrogate data to estimate intermediate- or long-term exposure, WHS uses the 90% UCL on the arithmetic mean. This UCL is used for the reasons stated in the preceding paragraph. As with short-term exposure estimates based on PHED subsets, multipliers corresponding to the median sample sizes over the three major body regions are used. For example, if the median sample size for hand is between 6 and 14, the multiplier is rounded to 2; if it is greater than 15, no multiplier is used since its numerical value is (rounded to) 1.

<u>(2) Data on/for the Surrogate Atrazine</u>. Six (6) worker exposure studies were submitted by registrants in support of the IRED for *atrazine* (U.S. EPA, 2003). One study was submitted in 7 volumes (Honeycutt *et al.*, 1996a, 1996b; Selman, 1996, 1998; Selman and Rosenheck,

1996a, 1996b, 1996c), as it included several amendments and interim reports. The study was conducted to monitor inhalation and dermal exposures for workers mixing/loading and applying various formulations of atrazine to corn using groundboom sprayers. In that study, biological monitoring (a.k.a., biomonitoring) of urine metabolites, passive dosimeters, and air sampling were used to determine the daily handler exposures to atrazine.

Samples in that corn study were collected at 19 test locations (5 in Illinois, 5 in Indiana, and 9 in Ohio). Individual test sites consisted of either multiple fields treated with atrazine, or commercial facilities where atrazine was loaded into carrier trucks or spray rigs. Sixteen males and one female were each monitored once, and another male was monitored twice, with the study report claiming a sampling yield of nearly 1 volunteer per site. Volunteers were monitored using inhalation and dermal (passive) dosimetry during the first 2 days of handling atrazine, while their urine samples were collected at each site prior to the initiation of the study and during all 3 days of the biomonitoring period that immediately followed.

The applicators in the above corn study, while each having 3 to 15 years of work experience, were responsible for driving the spray rigs, applying atrazine, and performing maintenance on the rigs and booms. They occasionally also cleaned spray rigs and coupled hoses from the nurse trucks to the spray rigs. The mixer/loaders were responsible for dispensing atrazine products from bulk supply tanks into large nurse trucks using metering devices and electronic valves. Where required, they also emptied the bags or jugs of atrazine dry flowable or wettable powder into the trucks to mix the spray solutions. In addition to driving the trucks, the truck tenders were responsible for coupling and uncoupling hoses to and from trucks, coupling truck hoses to spray rigs, and performing occasional maintenance on the trucks and the rigs.

A variety of atrazine products sold in various packaging (bagged, bulk, mini-bulk, etc.) and various quantities were used in the study. The amount of atrazine AI in those products ranged from 10.4 to 85.0%. Atrazine spray rates ranged from 0.91 to 1.98 lb AI per acre. The area sprayed ranged from 18 to 620 acres for each day over the two- to three-day period.

Dermal exposure was quantified using inner and outer body dosimeters, hand rinses, and head patches. Inhalation exposure was measured using personal air pumps at an air flow rate of approximately 1 L/min. The air pumps were left on all day, from when study subjects put on their worker clothes to their field return. Two urine samples, each covering a 12-hour interval within a 24-hour period, were collected from each volunteer prior to the study except for 5 subjects. For those 5 subjects, urine samples were obtained just prior to the initiation of the study. All urine samples, including those collected during the biomonitoring period, were measured for 3 chlorotriazine metabolites (coded G-28273, G-28279, G-30033) which were used to represent *total* chlorotriazine in urine.

Unfortunately, numerous inconsistencies or problems were found inherent in or associated with this atrazine study that had made its data unacceptable for worker exposure to atrazine, or as surrogate for worker exposure to simazine. First and foremost, as pointed out by U.S. EPA (2003), the number of volunteers in the biomonitoring phase was inconsistently reported among the several versions of the study document submitted for review (i.e., among the 7 volumes cited above). The number of urine sample replicates was inconsistently reported as well. Furthermore, the urinary data were not corrected for laboratory, field recovery, or storage losses.

Yet more importantly, one crucial deficiency found is that, as also noted by U.S. EPA (2003), it was impossible to determine the actual relationship between the amount of atrazine handled on a given day and the chlorotriazines excreted the next day, all because of the way in which the 24-hour urine samples were collected during the monitoring period. In fact, some of the highest daily doses observed in the volunteers were based on days in which they reportedly handled little or no atrazine.

Still another crucial issue was the study's uncommon choice of total chlorotriazine as the urinary residues for biomonitoring. The total chlorotriazine residues represented only 12% of total atrazine dose. It is common practice that a predominant metabolite be used as the biomarker for back-calculating the amount of parent compound (or in this case, atrazine) absorbed. There is a general preference or recommendation to use a metabolite that represents 30% or more of the original dose, in order to reduce the error for back-calculation of the dose for the parent compound. The primary metabolite of atrazine is its mercapturate, which has been used in other biomonitoring studies for atrazine, including in the National Hazardous Exposure Assessment Survey (as noted in U.S. EPA, 2003).

For the non-biomonitoring phase that relied on the use of body dosimeters and air samples, the problem was more with the recovery losses. These losses were to the levels that, based on PHED's criteria on data quality, the study results had all been graded C for inhalation, dermal covered, dermal uncovered, and all hand samples but one (Selman and Rosenheck, 1996a).

Lastly, there were several problems found common to both the passive dosimetry and the biomonitoring phase of this corn study. First, the majority of the volunteer workers used either an enclosed cab tractor for spraying or a closed system for mixing/loading. This additional protection is not required by any of the product labels. Another limitation or problem found with this study is that 4 of the 7 volunteers worked as a M/L/applicator doing more than what an applicator is typically responsible for. Still another problem is that the study made no effort to standardize the clothing worn by the volunteers or to alter any test subject's own normal work practice. These inconsistencies tended to *under*estimate the handler exposures at issue. The major variable that might have *over*estimated the exposures observed is that at least 3 of the 7 applicators monitored had spill-related exposure, which nonetheless could still be considered as an expected event.

Table 9 summarizes and compares the internal doses that were calculated by U.S. EPA (2003) from the PHED data and from the chemical-specific (atrazine) data in the corn study. While U.S. EPA's use of the geometric mean (GM) in their own comparison is inconsistent with current practice at WHS, the results of their calculations and comparison, even in terms of GM and not arithmetic mean, were sufficient to support the registrant's claim (Selman and Rosenheck, 1996a) that the exposure values in the corn study were comparable to those derived from PHED. It was for this reason, as well as for the deficiencies and inconsistencies noted above, that where applicable PHED data were used in this exposure assessment.

Table 9. Internal Doses of Atrazine Calculated from Three Sets of Data That Were Obtained or Surrogated for Three Handler Groups[a]

Handler Group[b]	Dosimeter-Based		Biomonitoring		PHED[c]
Applicator	high	2.1×10^{-2}	high	7.9×10^{-3}	
	low	6.4×10^{-5}	low	8.6×10^{-5}	
		GM 7.7×10^{-4}		*GM* 6.1×10^{-4}	*GM* 2.7×10^{-4}
Mixer/Loader	high	1.6×10^{-2}	high	2.5×10^{-3}	
	low	6.5×10^{-5}	low	2.8×10^{-5}	
		GM 7.3×10^{-4}		*GM* 3.8×10^{-4}	*GM* 6.7×10^{-4}
M/L/Applicator	high	1.6×10^{-2}	high	4.6×10^{-3}	
	low	1.7×10^{-5}	low	1.0×10^{-3}	
		GM 1.3×10^{-3}		*GM*[d] 2.8×10^{-3}	*GM* 9.4×10^{-4}

[a] from U.S. EPA (Bangs and Becker, 2002); all doses in mg/lb atrazine handled and based on an absorption rate of 5.6% for dermal exposure to atrazine where applicable; GM = geometric mean.

[b] the mixer/loaders from the body dosimetry and the biomonitoring phase including truck tenders as so categorized in the corn study on atrazine (Selman and Rosenheck, 1996a, 1996b, 1996c), with which U.S. EPA made the above comparison; M/L/applicator = mixer/loader/applicator.

[c] from the nonchemical-specific Pesticide Handler Exposure Database (PHED, 1995), which does not provide a range; assuming enclosed cab and groundboom for applicators without gloves and closed system for M/L/truck tenders with gloves, all wearing long pants and long sleeves.

[d] no GM was given by U.S. EPA (Bangs and Becker, 2002); shown here is the midrange which can be treated as the GM since the range is fairly short.

The other five handler exposure studies, of which four were sponsored by ORETF, focused on M/L/applicator exposures from use of spray or the granular formulations on *turf*. In the one non-ORETF study (Rosenheck *et al.*, 1993), three exposure scenarios were characterized: (1) lawn treatment using a home-use *push* type cyclone spreader; (2) lawn treatment using a home-use type *hand* cyclone spreader; and (3) commercial lawn care operators (LCO) mixing/loading and handgun spraying to large(r) client lawns. This non-ORETF study was conducted in three locations (2 in North Carolina and 1 in Georgia). Eight experienced volunteers were monitored at the three sites, with 15 replicates per site (except in the one case where one handgun operator could not proceed with the application due to mechanical failure with his application equipment).

Dermal exposures in the above non-ORETF study were monitored by use of 100% cotton long underwear as whole body dosimeters, worn underneath normal work clothes. Exposures to hands, face, and neck were estimated through hand rinses, face swipes, and neck swipes, respectively. Inhalation exposure was monitored using personal air sampling pumps attached to glass fiber filters. Controls and two fortification samples were run concurrently with each set of field samples. Field recovery levels ranged from 61.5 to 98.2%.

Table 10 presents the arithmetic means and the standard deviations (SD) re-calculated from the raw exposure data on handgun use provided in the study, as only GM (and the individual) values were given in that study. That study separated the exposure of handgun mixer/loaders from the exposure of handgun applicators. Given that the entire spray operation at each site was completed in roughly 1 hour, the two handling tasks can easily be performed by the same person in a workday. The present exposure assessment thereby undertook the effort to combine the exposures monitored for the two handling tasks to provide a potential worst-case scenario for M/L/Applicators from handgun use. The data on spreader use were not included in Table 10 since simazine is now no longer available as a (*non*water-dispersible) granule.

Table 10. Exposures to Atrazine from Applications with Handgun in North Carolina and Georgia[a]

M/L/Applicator[b]	Dermal		Hand		Inhalation	
	average	SD	average	SD	average	SD
Handgun Spray	9.3	7.4	4.4	5.9	0.55	0.70

[a] from Rosenheck *et al.* (1993) using clothing dosimeters and air samples, based on 5 replicates per site (except in the one case where one handgun operator could not proceed with the spray due to mechanical failure with his spray equipment) at 3 test sites (2 in North Carolina and 1 in Georgia); average = *arithmetic* mean, in μg/lb atrazine handled per kg of body weight (adjusted for spike recovery); SD = standard deviation; dermal = total dermal − hand.

[b] mixer/loader/applicators (M/L/Applicators) who used a handgun to spray atrazine to (larger) turf areas, which required roughly 1 hour to complete; all volunteers wore gloves.

Of the four ORETF studies, two were based on the use of herbicides in liquid formulation and hence were considered in the present exposure assessment. These two studies included exposure monitoring for: (1) homeowners using a hose-end sprayer (Klonne *et al.*, 1999a); and (2) LCO using a truck-mounted hose with a handgun sprayer (Klonne *et al.*, 1999b).

The first ORETF study (Klonne *et al.*, 1999a) was conducted to monitor exposures for home-owners either applying a liquid diazinon with a ready-to-use (RTU) hose-end sprayer, or loading and applying diazinon in a more concentrate liquid formulation with a dial-type hose-end sprayer (DTS). This diazinon study used 30 volunteers each in the RTU and the DTS trial. Each of the 60 replicates (i.e., with 30 for RTU and another 30 for DTS) consisted of a spray application to roughly 5,000 ft^2 of turf on residential lawns in Maryland. The average time of each spray application was approximately 75 minutes. The reported GM for total dermal depositions on the T-shirt and shorts, including the exposed skin, for the RTU and the DTS homeowner users were 33 and 129 μg/kg per lb of AI handled, respectively. For both the RTU and the DTS user groups, much of the diazinon deposition was found on the hands and lower legs. The GM inhalation exposures for the two homeowner user groups were 0.15 and 0.25 μg/kg per lb AI handled, respectively.

The second ORETF study (Klonne *et al.*, 1999b) was conducted to monitor the dermal and inhalation exposures of 17 LCO volunteers, who each handled about 5 lb of DCPA in one of four liquid formulations for a total of roughly 2.5 acres of turf area in Ohio, Maryland, or

Georgia. The four liquid formulations used were flowable, water dispersible granule, soluble bag, and a wettable powder (WP), with each taking up 15 replicates for LCO not only applying but also mixing/loading the herbicide. An additional 30 replicates were sampled to measure the exposure for LCO applying the WP formulation without performing any mixing or loading task. The WP was used for this applicator-alone phase (at least for comparison purposes) because this liquid formulation was expected to result in the highest exposure during the mixing/loading task, thus providing presumably the best opportunity to estimate the impact of mixing/loading (i.e., without the application portion), if any, on handler exposure. Given that quite a few subgroups were covered in that study, a special effort was made to have those study results summarized in Table 11 below.

Table 11. Average Dermal and Inhalation Exposures from Handling Various Formulations of DCPA to Turf in Ohio, Maryland, or Georgia[a]

Worker Group/Formulation	Replicates	Exposure (μg/lb AI handled/kg BW)[b]		
		Dermal	Hand	Inhalation
Mixer/Loader/Applicator				
Flowable	15	9.1	0.38	0.03
Water Dispersible Granules	15	20.6	0.47	0.53
Water-soluble Bag	15	12.3	0.57	0.21
Wettable Powder	15	13.7	0.55	2.2
Applicator Only				
Wettable Powder	30	21.5	0.62	0.02
Average (of all 5 trials)[c]		*15.4 ± 30.2*	*0.52 ± 0.47*	*0.60 ± 0.76*

[a] from Klonne *et al.* (1999b), with trial applications each based on the maximum label rate of 2.0 lb DCPA (dimethyl tetrachloroterephthalate) per acre; the 5 trials collectively involved 17 professional lawn care operator (LCO) volunteers all wearing normal work clothes plus gloves.

[b] based on each LCO's individual body weight (BW); AI = active ingredient; dermal exposure was measured on long underwear suits (i.e., the inner body dosimeters) plus the exposed skin area, with the lower and upper legs accounting for ~80% of the total; dermal = total dermal – hand.

[c] average = *arithmetic* mean, with standard deviation taken from all 5 trials including the one for wettable powder (WP) applicators only; the WP applicators only were included in the average here as WP mixer/loader/applicators primarily because the data from the two WP trials supported the notion that the exposure from mixing/loading was negligible compared to that from spraying alone.

Note that of the two ORETF studies discussed above, data from only the second were used directly as surrogates in the present exposure assessment. The exposure data from this DCPA, second study (i.e., those in Table 11) were used here as a last resort as PHED data were not available for this handler group. The diazinon (i.e., the first) study was considered for cross-reference purposes only in part because the RTU and DTS trials used liquid formulations less comparable to those in which simazine is available. Another reason is that the hose-end sprayers in the RTU and DTS trials were also considered not comparable to the low-pressure truck-mounted hoses each with a handgun controlled sprayer typically used by LCO. It is for this same reason that the discussion on the diazinon study was based on its original, reported GM, and not on the arithmetic means (which the study did not provide but could be back-calculated from the raw data that were provided). The exposure data from the non-ORETF study by Rosenheck *et al.* (1993) were also used for cross-reference only because they used only a single liquid formulation of atrazine and only one type of handgun sprayer.

C. Applicators

As indicated in Table 5, in the present exposure assessment two applicator subgroups were included according to both the product formulation available and the type of application equipment used. The two applicator subgroups were: (1) pilots spraying simazine liquid (such as from flowable, dry flowable, water-dispersible granule) to pre-plant soil from an aircraft; and (2) operators applying simazine liquid to soil using a groundboom sprayer.

Of the two applicator subgroups included here, pseudo chemical-specific data on applicator exposure were available only for those spraying liquid *atrazine* with groundboom sprayers. Nonetheless, as discussed in the preceding subsection (*Data on/for the Surrogate Atrazine*), numerous significant flaws were reportedly associated with the atrazine data that had made them unacceptable as surrogates for worker exposure to simazine. Therefore, more generic data from PHED subsets (Appendices B-1 and B-2) were used to estimate the exposure rates for the two applicator subgroups, as footnoted in Table 5.

D. Human Flaggers

In some places, ground personnel are still employed to guide an aircraft's pass by waving flags, despite the fact that in other places mechanical devices are used to do more or less the same. These human flaggers are in fields to indicate to their pilots (i.e., pesticide operators) the starting point for each pass. For reasons similar to those stated in the above subsection for applicator exposure, data from a PHED subset were used to estimate the exposure rates for human flaggers. The assumptions and the data used are summarized in Table 6.

E. Mixer/Loaders

As the different formulations and various application methods each have their own direct impact on the inhalation and dermal exposures of mixer/loaders handling simazine, this handler group was further divided into five (5) subgroups accordingly. These five subgroups were: (1) those handlers mixing/loading flowable concentrate for aerial spray; (2) those mixing/loading dry flowable for aerial spray; (3) those mixing/loading flowable for ground-boom spray; (4) those mixing/loading dry flowable for groundboom spray; and (5) those mixing/loading dry flowable for chemigation/microsprinkler irrigation. As footnoted in Table 2, only one product label (Drexel Simazine 4L) and one SLN label allow (macro)sprinkler-type and microsprinkler-type irrigation, respectively. For exposure assessment purposes and taking into account the tasks involved, here dry flowable included water-dispersible granule.

For reasons similar to those stated above for applicator and flagger exposures, nonchemical-specific data from PHED subsets were used to estimate the dermal and inhalation exposure rates for the 5 subgroups of mixer/loaders handling simazine. The exposure data and the assumptions used are summarized in Table 7.

F. M/L/Applicators

For application of liquid simazine to turf or soil areas, three common major types of handheld sprayers are often used. These are: (1) low-pressure handgun or handwand (for most lawn or soil areas); (2) occasionally high-pressure handgun (for extensive areas such as turf farm); and (3) backpack type (for hard-to-reach areas). Technically, these three types of sprayers can each be further subdivided according to spray solutions prepared from either dry flowable or flowable concentrate. However, such a distinction was deemed unnecessary, in that the exposures from mixing/loading the two flowable formulations were not expected to vary significantly in that the duration involved here for mixing/loading is supposed to be very short. In fact, an earlier data review (Dong, 1998) supported that M/L/applicators typically would each spend less than 10 or 15% of their workday in mixing/loading a pesticide.

The DCPA data (Klonne *et al.*, 1999b) discussed earlier were used to estimate the exposure rates for M/L/applicators using a low-pressure handgun/handwand sprayer. As a cross-reference, also considered for this scenario were the atrazine data provided by Rosenheck *et al.* (1993). PHED data were used for the other two types of sprayers, since no (other) suitable surrogate data were available. The data and the assumptions used are summarized in Table 8, which includes use scenarios in the agricultural setting where growers occasionally may spot-treat certain areas (e.g., between trees) with one of the handheld types listed in this table.

G. Short-and Long-Term Exposures

Tables 12 through 15 provide the estimates of absorbed daily dosage (ADD) for the short-, intermediate-, and longer-term worker exposures to simazine under the four handler scenarios summarized in Tables 5 through 8. Here in line with the interim guidelines given at WHS, short- and intermediate-terms were defined as up to 7 days and as 8 days to 3 months, respectively. The dosage estimates in Tables 12 through 15 were each calculated with their corresponding data and assumptions listed in Tables 5 through 8. As footnoted in Tables 12 through 15, three additional variables were required for the calculations. Where applicable, two of the variables were statistical parameters, with one involving the use of the 90% upper tolerance limit of the 95th percentile as the upper-bound for short-term exposure, and the other based on the use of the 90% UCL on the calculated mean as an average ADD for exposures longer than short-term, as discussed in Subsection V-1.B(1) on PHED Data. The third variable was exposure frequency, as discussed in the following subsection.

H. Exposure Frequency

No temporal data were available for the direct projection of an *individual* worker's exposure frequency. Temporal patterns on seasonal use for handlers (and fieldworkers) have been projected using the PUR data, which can only be as descriptive as listing each AI's use by county, crop/site, pounds used, number of applications, acres, general application method (i.e., aerial *vs*. ground), etc. Because simazine is used mainly for the control of weed growth, which has its particular short season not well reflected in the PUR data, temporal patterns for handler exposure to this herbicide were necessarily based on a different set of conservative and yet realistic assumptions. Simazine has its own use season because it is one of those herbicides inhibiting weed growth mainly at the stage of seed germination or seedling establishment. Herbicides of this type have a short use window in that they usually will not (be used to) control annuals after the weeds start to grow or after their seeds have germinated.

Table 12. Estimates of Absorbed Daily Dosages (ADD, in μg/kg/day) for Applicators from Agricultural Use of Simazine

Application[a] and Formulation	Average[a] ADD			Acute[b] ADD		Seasonal[c] ADD		Annual[d] ADD	Lifetime[e] ADD
	dermal	hand	inhalation	multipliers	total	multipliers	total		
Liquid									
aerial	134.3	24.6	24.4	6, 6, 5	1,075.4	2, 2, 2	366.6	61.1	32.6
groundboom	9.0	19.5	8.6	4, 4, 4	148.4	1, 1, 1	37.1	6.2	3.3

[a] from Table 5 in this document; dermal = total dermal – hand.

[b] the multipliers (*see* PHED Data under Subsection V-1.B(1) for definition) from left to right are listed for the dermal, hand, and inhalation component, respectively, and for each PHED subset considered; acute ADD total = [(average ADD for dermal) x (acute multiplier for dermal) + (average ADD for hand) x (acute multiplier for hand) + (average ADD for inhalation) x (acute multiplier for inhalation)].

[c] each intermediate-term or seasonal ADD (SADD) total was calculated in a manner similar to that calculated for the acute ADD total (i.e., as in footnote *b*), except that it has its own set of multipliers.

[d] annual or annualized ADD (AADD) = SADD x (annual use months per year, here 2 months was assumed, *see* the text and Appendix C for justification) x (12 months in a year)$^{-1}$.

[e] lifetime ADD = AADD x (40 years of work in a lifetime) x (75 years in a lifetime)$^{-1}$.

Table 13. Estimates of Absorbed Daily Dosages (ADD, in μg/kg/day) for Aerial Human Flaggers from Agricultural Use of Simazine

Application[a] and Formulation	Average[a] ADD			Acute[b] ADD		Seasonal[c] ADD		Annual[d] ADD	Lifetime[e] ADD
	dermal	hand	inhalation	multipliers	total	multipliers	total		
Liquid									
aerial	96.1	1.5	8.6	4, 4, 4	428.4	1, 1, 1	106.2	17.7	9.4

[a] from Table 6 in this document; dermal = total dermal – hand.

[b] the multipliers (*see* PHED Data under Subsection V-1.B(1) for definition) from left to right are listed for the dermal, hand, and inhalation component, respectively, and for each PHED subset considered; acute ADD total = [(average ADD for dermal) x (acute multiplier for dermal) + (average ADD for hand) x (acute multiplier for hand) + (average ADD for inhalation) x (acute multiplier for inhalation)].

[c] each intermediate-term or seasonal ADD (SADD) total was calculated in a manner similar to that calculated for the acute ADD total (i.e., as in footnote *b*), except that it has its own set of multipliers.

[d] annual or annualized ADD (AADD) = SADD x (annual use months per year, here 2 months was assumed, *see* the text and Appendix C for justification) x (12 months in a year)$^{-1}$.

[e] lifetime ADD = AADD x (40 years of work in a lifetime) x (75 years in a lifetime)$^{-1}$.

Table 14. Estimates of Absorbed Daily Dosages (ADD, in μg/kg/day) for Mixer/Loaders from Agricultural Use of Simazine

Application[a] and Formulation	Average[a] ADD			Acute[b] ADD		Seasonal[c] ADD		Annual[d] ADD	Lifetime[e] ADD
	dermal	hand	inhalation	multipliers	total	multipliers	total		
Flowable									
aerial	1,113.4	149.6	102.9	4, 4, 4	5,463.5	1, 1, 1	1,365.9	227.6	121.4
groundboom	185.6	25.0	17.1	4, 4, 4	911.0	1, 1, 1	227.8	38.0	20.3
chemigation[f]	445.4	59.8	41.1	4, 4, 4	2,185.6	1, 1, 1	546.4	91.1	48.6
Dry-Flowable[g]									
aerial	496.3	24.9	30.0	4, 4, 4	2,204.8	1, 1, 1	551.2	91.9	49.0
groundboom	82.7	4.2	5.0	4, 4, 4	367.6	1, 1, 1	91.9	15.3	8.2

[a] from Table 7 in this document; dermal = total dermal – hand.

[b] the multipliers (*see* PHED Data under Subsection V-1.B(1) for definition) from left to right are listed for the dermal, hand, and inhalation component, respectively, and for each PHED subset considered; acute ADD total = [(average ADD for dermal) x (acute multiplier for dermal) + (average ADD for hand) x (acute multiplier for hand) + (average ADD for inhalation) x (acute multiplier for inhalation)].

[c] each intermediate-term or seasonal ADD (SADD) total was calculated in a manner similar to that calculated for the acute ADD total (i.e., as in footnote *b*), except that it has its own set of multipliers.

[d] annual or annualized ADD (AADD) = SADD x (annual use months per year, here 2 months was assumed, *see* the text and Appendix C for justification) x (12 months in a year)$^{-1}$.

[e] lifetime ADD = AADD x (40 years of work in a lifetime) x (75 years in a lifetime)$^{-1}$.

[f] including microsprinkler irrigation.

[g] including water-dispersible granule.

Table 15. Estimates of Absorbed Daily Dosages (ADD, in µg/kg/day) for Mixer/Loader/Applicators from Agricultural Use of Simazine

Application[a] and Formulation	Average[a] ADD			Acute[b] ADD		Seasonal[c] ADD		Annual[d] ADD	Lifetime[e] ADD
	dermal	hand	inhalation	multipliers	total	multipliers	total		
Flowable									
low-pressure	4.6	0.16	3.0	*(9.1; 0.14; 3.8)*	33.8	n/a	7.8	1.3	0.7
high-pressure	141.0	7.3	53.9	5, 5, 5	1,010.0	2, 2, 2	404.4	67.4	35.9
backpack	95.6	0.04	1.3	6, 6, 6	581.6	2, 2, 2	193.9	32.3	17.2

[a] from Table 8 in this document; dermal = total dermal – hand.

[b] in parentheses from left to right are standard deviations (SD) for the dermal, hand, and inhalation component, respectively, as shown in Table 11 after adjustment for different inhalation rate used, different daily usage, and dermal absorption; the multipliers from left to right are likewise for the dermal, hand, and inhalation component, respectively, and for each PHED subset considered; acute ADD total = [(average ADD for dermal) x (acute multiplier for dermal) + (average ADD for hand) x (acute multiplier for hand) + (average ADD for inhalation) x (acute multiplier for inhalation)]; where multipliers (*see* PHED Data under Subsection V-1.B(1) for definition) were not available, acute ADD total = [(average ADD for dermal + 2SD) + (average ADD for hand + 2SD) + (average ADD for inhalation + 2SD)], *see* Subsection VI-1 for rationale for use of SD in the above manner; note that here each SD was derived from multiplying the mean at issue by the ratio of the SD to the mean listed in Table 11 (i.e., taking the position that the coefficient of variation should remain the same).

[c] each intermediate-term or seasonal ADD (SADD) total was calculated in a manner similar to that calculated for the acute ADD total (i.e., as in footnote *b*), except that it has its own set of multipliers.

[d] annual or annualized ADD (AADD) = SADD x (annual use months per year, here 2 months was assumed, *see* the text and Appendix C for justification) x (12 months in a year)$^{-1}$.

[e] lifetime ADD = AADD x (40 years of work in a lifetime) x (75 years in a lifetime)$^{-1}$.

In the present exposure assessment, it was assumed that some workers could handle simazine for as long as 60 (more or less consecutive) days per season as well as per year. Justification for this assumption was attached at the end of this assessment document as Appendix C.

2. Handler Exposure from Non-Agricultural Use

For handler exposure from non-agricultural use, M/L/applicators were the only individuals considered in this exposure assessment. This consideration was based on the assumption that for herbicides used in a non-agricultural setting, a single person can accomplish the entire day's operation. The general expectation is that for a task that does not last a full workday (i.e., 8 hours), the *daily* exposure for a M/L/applicator handling a pesticide is greater than that for any individual working either as an applicator or as a mixer/loader alone.

A. Commercial M/L/Applicators

The data and assumptions used for this worker group are summarized in Table 16, whose content is identical to that of Table 8 (that presenting for their agricultural counterparts). The daily exposures were expected to be the same for both the agricultural and nonagricultural settings because the rest of the specifics in their use scenarios remain the same.

B. Short-and Long-Term Exposures

Table 17 provides the ADD estimates for the short-, intermediate-, and long-term handler exposures to simazine for *commercial* M/L/applicators. The various ADD estimates listed in the table are thus identical to those listed in Table 15 for exposure of M/L/applicators from agricultural use (inasmuch as Table 16 is identical to Table 8). As footnoted in Table 17, the same three variables considered in Subsection V-1.G were used in calculating the ADD estimates. Two of the variables again were both an upper-bound ADD for acute exposure and a more conservative estimate for the average ADD for intermediate-term exposure. The third variable likewise was exposure frequency, for which again the estimate was assumed to be 60 days for the reasons given previously for agricultural handlers (as presented in Appendix C).

C. Homeowner Users

For this group of non-occupational users, the data and the assumptions used are summarized in Table 18. As explained in the next paragraph, the daily usage of simazine by homeowner users was assumed to be roughly 5 times less than those by their counterpart commercial M/L/applicators. Seasonal and long-term ADD estimates were not computed for homeowner users given that they each are not expected to apply any of the simazine products for more than a couple of times a year. In addition to lower daily and no seasonal usage, homeowners are not expected to use, in the case for turf treatment, a backpack sprayer or a high-pressure type handwand sprayer.

Compared to the commercial M/L/applicators, homeowner users are expected to work 5 times less in a given day in that none of the home-use applications should take more than 1 or 2 hours to complete, as well reflected in the ORETF studies discussed earlier. In contrast, there is a much greater potential for professional LCO each to work for multiple clients in a neighborhood in a given day (up to 8 or 9 hours including travel time). In short, the ADD values given in Table 18 for homeowner users were based on a daily exposure of 1 to 2 hours long, whereas those in Table 17 for LCO were based on a daily exposure of 8 to 9 hours long.

Table 16. Data and Assumptions Used for Estimation of Simazine Dosage for Mixer/Loader/Applicators from *Non*-Agricultural Use

Application and Formulation	Median[a] Numbers	Exposure (µg/lb AI handled)[b]			Acres[c] per Day	Rate[d] (lb AI/acre)	Absorbed Daily Dosage (ADD, µg/kg BW/day)[e]			
		Dermal	Hand	Inhalation			Dermal	Hand	Inhalation	Total
Flowable										
low-pressure[f]	15, 15, 15	1,080	36.3	41.6	1	2	1.9	0.06	1.2	3.1
high-pressure[g]	13, 13, 13	6,580	339.0	151.0	5	2	56.4	2.9	21.6	80.9
backpack[n]	11, 11, 11	22,300	9.7	17.5	1	2	38.2	0.02	0.5	38.7

[a] median numbers of observations for dermal, hand, and inhalation, respectively, either in the Pesticide Handler Exposure Database (PHED, 1995) subset used or in the exposure monitoring study cited in footnote *f* below.

[b] appropriate personal protective equipment was applied as per label specifications (i.e., gloves, long pants, long sleeves, no respirator); dermal = total dermal – hand.

[c] default maximum acres/day, as discussed in the text (Subsection V-1.A: *Daily Acreages and Application Rates*).

[d] maximum label rate, as discussed in the text (Subsection V-1.A: *Daily Acreages and Application Rates*).

[e] total absorbed dosage (µg/kg/day) = [(dermal + hand + inhalation) absorbed dosage] = [{(dermal + hand exposure rate) x (6% dermal absorption, *see* Subsection III-2) + (inhalation exposure rate) x (100% default inhalation uptake, *see* Subsection III-2)} x {(application rate) x (acres/day) x (70 kg default body weight, Thongsinthusak *et al.*, 1993a and U.S. EPA, 1997)$^{-1}$}].

[f] from Klonne *et al.* (1999b) on DCPA (dimethyl tetrachloroterephthalate) as presented in Table 11 in this document, after normalization to a default body weight of 70 kg; note that no adjustment was made for the respiration rate as that study used the same default rate of 16.7 L/m (actually reportedly 17 L/m); taking the average of all formulations used (flowable, water dispersible granules, and wettable powder) while using the handgun data by Rosenheck *et al.* (1993) on atrazine (as presented in Table 10 in this document) for cross-reference; here handgun was considered as operating in low pressure (as a worst-case).

[g] PHED subset presented in Appendix B-6.

[h] PHED subset in presented Appendix B-7.

Table 17. Estimates of Absorbed Daily Dosages (ADD, in μg/kg/day) for Mixer/Loader/Applicators from *Non*-Agricultural Use of Simazine

Application[a] and Formulation	Average[a] ADD			Acute[b] ADD		Seasonal[c] ADD		Annual[d] ADD	Lifetime[e] ADD
	dermal	hand	inhalation	multipliers	total	multipliers	total		
Flowable									
low-pressure	1.9	0.06	1.2	*(3.6; 0.06; 1.5)*	13.4	n/a	3.1	0.52	0.28
high-pressure	56.4	2.9	21.6	5, 5, 5	404.4	2, 2, 2	161.8	27.0	14.4
backpack	38.2	0.02	0.5	6, 6, 6	232.5	2, 2, 2	77.5	12.9	6.9

[a] from Table 16 in this document; dermal = total dermal – hand.

[b] in parentheses from left to right are standard deviations (SD) for the dermal, hand, and inhalation component, respectively, as shown in Table 11 after adjustment for different inhalation rate used, different daily usage, and dermal absorption; the multipliers (*see* V-1.B(1) for definition) from left to right are likewise for the dermal, hand, and inhalation component, respectively, for each PHED subset considered; acute ADD total = [(average ADD for dermal) x (acute multiplier for dermal) + (average ADD for hand) x acute (multiplier for hand) + (average ADD for inhalation) x (acute multiplier for inhalation)]; where the individual multipliers were not available, the corresponding 2SD were used instead, *see* Subsection VI-1 for rationale for use of SD in the above manner; note that here each SD was derived from multiplying the mean at issue by the ratio of the SD to the mean listed in Table 11 (i.e., taking the position that the coefficient of variation should remain the same).

[c] each intermediate-term or seasonal ADD (SADD) total was calculated in a manner similar to that calculated for the acute ADD total (i.e., as in footnote *b*), except that it has its own set of multipliers and that the SD were not used even when multipliers were not available; n/a = not applicable.

[d] annual or annualized ADD (AADD) = SADD x (annual use months per year, here 2 months was assumed, *see* the text and Appendix C for justification) x (12 months in a year)$^{-1}$.

[e] lifetime ADD = AADD x (40 years of work in a lifetime) x (75 years in a lifetime)$^{-1}$.

Table 18. Estimates of Absorbed Daily Dosages (ADD, in μg/kg/day) for Homeowner Mixer/Loader/Applicators

Application[a] and Formulation	Average[a] ADD			Acute[b] ADD	
	dermal	hand	inhalation	standard deviation	total
Flowable					
low-pressure	0.4	0.01	0.2	(0.72; 0.012; 0.30)	2.7

[a] from Table 17; dermal = total dermal − hand; both the average absorbed daily dosage (ADD, in μg per kg body weight per day) and its associated standard deviation (SD) were adjusted for the daily usage that was assumed to be 5 times less due to the presumption that homeowners would work fewer hours in any given day compared to their counterpart professional lawn care operators (*see* the text for further discussion).

[b] acute ADD total = [(average ADD for dermal + 2SD) + (average ADD for hand + 2SD) + (average ADD for inhalation + 2SD)], *see* Subsection VI-1 for rationale for use of SD in the above manner.

Backpack sprayers are intended for difficult-to-reach spots where a conventional pressurized tank sprayer cannot be moved around effectively. They are also used for those relatively larger difficult-to-reach areas where the use of a plastic bottle sprayer becomes inefficient. Nonetheless, it is fair to say that homeowners are not likely to use a backpack sprayer, even if they have one, for simazine type application to their lawns because the effort of walking over each spot to be sprayed takes its toll on the operator’s strength. Furthermore, in most cases with spot treatment on residential lawns, the use of a plastic bottle sprayer is much more practical and efficient. And even when the homeowner opted to use a backpack sprayer for spot type treatment, the exposure encountered would not greatly exceed that from using a plastic bottle or low-pressure sprayer due to the short use duration involved.

On the other hand, as indicated in Table 16, the dermal exposure rate can be extremely high for backpack operators. This expectation is based on the general observation that in some cases backpack operators tend to walk towards where they are directing their spray and walk past *tall* and *full* foliage that has just been treated (Matthews, 1992). While it is debatable whether or not commercial M/L/applicators would ever encounter this type of exposure, the chance is even slimmer for homeowners spot-treating weeds on their own lawns or in their own gardens. The same argument also holds true for the use of high-pressure handwand or handgun sprayers.

3. Nonuser Residents

Nonuser residents may be exposed inadvertently to some simazine residues from application around homes, as it must be assumed that they may enter or pass through treated residential areas within a few hours of treatment (i.e., as soon as after the sprays have dried as per label specification). Activities such as walking or playing on the treated lawn or on the soil around or underneath may bring residents in contact with residues by the dermal, inhalation, or hand-to-mouth route of exposure. Insofar as nonuser residents are not advised to wear protective clothing when playing on or reentering their treated properties, it must also be assumed that nearly all parts of their body are available for dermal contact.

In real life, however, both the application method used for and the physiochemical properties of simazine preclude much residential exposure from many of the pathways discussed above. For one thing, as noted earlier, simazine has a very low vapor pressure (Table 1) so there is limited opportunity for any significant inhalation exposure to occur in residential areas. The water drench that follows the application often washes much of the applied simazine residues into the treated thatch and soil. This process also increases accessible surface area of soil particles, which will adsorb much of the herbicide residues thereby further reducing their availability for dermal contact or inhalation exposure.

Mowing the lawn on a treated property initially could be thought of as another potential source of (considerable) exposure via the dermal or even the respiratory route. This potential exposure is mitigated by several circumstances, nonetheless. Shoes, in particular, will provide protection from the most likely site of dermal exposure for soil or turf residues. It has been assumed that normal work clothes, gloves, and shoes each have the effect of mitigating 90% of dermal exposure to pesticides for the body region that they each specifically protect (Thongsinthusak *et al.*, 1993a; Aprea *et al.*, 1994). Again, the need for water drench should already have the effect of reducing much of the turf residues available for dermal (foot) contact (and inhalation exposure).

Most lawn mower operators are therefore subject to minimal contact with pesticide residues following application to lawns. This minimal contact, together with the infrequency of lawn mowing by homeowners, is expected to further reduce the likelihood of their exposure to simazine residues remaining on treated lawns. (Even for commercial LCO who work for several clients in a day's work, their dermal contact should still be expected to be minimal because not all their clients' lawns are likely to be previously treated with simazine or treated with simazine on the same day or in the same week.) Moreover, it is important to note that, as stated in the Introduction section, simazine's mode of herbicidal action is through inhibition of photosynthesis, meaning that the herbicide is not expected to be *broadcast* sprayed over the entire lawn full of otherwise healthy and well-grown turfgrass. In other words, the bulk of the turfgrass to be mowed is not expected to bear much of the simazine residues.

There should be little or no concern that soil residues from a simazine treatment could be absorbed into host fruit as an additional source of dietary intake. This unlikelihood may be substantiated by a study on diazinon which may serve as an approximate surrogate for translocation of soil residues. In that study, which was conducted by U.S. Department of Agriculture (Fairchild, 1983) nearly three decades ago, one application of diazinon was made at 5 lb AI/acre to soil underneath various apricot, lemon, and orange trees grown at sites located in Santa Clara County, California. A second application was made between 21 and 35 days following the first. Soil, fruit, and leaves were sampled before treating and at various time intervals after the first application. Over 100 fruit and leaf samples were measured. All the post-application samples taken from the apricot and the orange trees were below the detection limit. Two leaf samples from the lemon trees taken 21 days post-first application had diazinon residues below 0.03 ppm. Three fruit samples collected from the lemon trees at 35 days post-first application contained diazinon residues ranging from 0.01 to 0.08 ppm (i.e., 10 to 80 μg AI per 2.2 lb fruit). These residue levels are considered negligible; and simazine is not supposed to be applied around the harvest stage. Furthermore, because simazine is more a pre- than a post-plant herbicide, it is very unlikely that fruit or foliage could be contaminated by splashing of the material during application.

A. Uptake and Intake from Treated Soil

Studies on *timed* degradation of simazine in soil were not available, making it difficult to estimate the dermal uptake and the oral intake of simazine residues in soil. A theoretical maximum of 22.5 mg AI per kg of soil (i.e., 22.5 ppm) was estimated in Subsection IV-4 for soil residues based on a single spray at the maximum label rate of 5 lb AI/acre. At the maximum rate of 2 lb AI/acre to turf soil, this theoretical maximum could reach 27 ppm after a reasonable maximum of 3 simazine applications were made to the same soil area within a reasonable (short) period of 6 months, based on the observation that simazine is resistant to physical and chemical dissipation in the soil. Using the theoretical maximum of 27 ppm as the turf soil residue level, the upper-bound dermal uptake would be around 0.6 μg/kg/day for a two-year-old child with a default average body weight (BW) of 12 kg (U.S. EPA, 1997).

The above soil dermal uptake was calculated with the following algorithm, as previously used by Dong *et al.* (1994) and U.S. EPA (1997): Soil dermal uptake = 0.6 μg/kg/day = (27 mg/kg upper-bound soil residues) x (1.5 mg/cm^2 upper-bound soil-to-skin adherence per 1 hr event/day) x (3,000 cm^2 BSA) x (6% dermal absorption, Subsection III-2) x (12 kg BW)$^{-1}$], where BSA = body surface area first based on the formula [BSA = (4 x BW)/(BW + 90)] by Costeff (1966) and then taking 55% as the exposed area subject to skin-soil loading as used by Thompson *et al.* (1992). The soil-to-skin adherence rate of 1.5 mg/cm^2 was that used by Dong *et al.* (1994) and suggested in U.S. EPA (1997). This upper-bound uptake of 0.6 μg/kg/day may also be considered as the upper-bound for adults gardening in treated soil or performing other similar reentry activities, since gardening appears to be less contact intensive than some children's outdoor activities and since a two-year-old child has the highest BSA to BW ratio and is likely to have the worst mouthing behavior (compared to all other age groups except infants whose access to soil residues is limited anyway).

The upper-bound daily soil ingestion rate has been assumed to be 1,000 mg and 10,000 mg for children with normal mouthing behavior and pica, respectively (e.g., Dong *et al.*, 1994; U.S. EPA, 1997). Based on these assumed daily soil ingestion rates and on the maximum soil residue level of 27 ppm estimated above, the upper-bound soil ingestion would be 2.2 μg/kg/day [= (27 mg/kg soil residues) x (1,000 mg/day soil ingestion rate) x (100% as the default oral absorption rate) x (12 kg BW)$^{-1}$] for the two-year-old with normal mouthing behavior. For children of the same age having pica, the upper-bound soil ingestion thus would be 22 μg/kg/day, given that their daily soil ingestion rate was assumed to be 10 times higher than children having normal mouthing behavior.

B. Uptake and Intake from Treated Turf

As noted in Subsection IV-3, one turf residue study (Rosenheck, 1999) was supposed to be available for use to estimate the magnitude of the simazine TTR and their half-life on turf. However, that subsection also points out the very problem with measuring TTR type samples. More specifically, to this date there has been no standardized or reliable methodology that can be used to measure even consistently, if not accurately, the TTR due largely to the way in which the TTR may be collected for analysis (e.g., Welsh *et al.*, 2005). When the residues in question for any given time point cannot be measured consistently or accurately, the transfer rate approach becomes useless. Otherwise, like with DFR (dislodgeable foliar residues), the dermal reentry exposure can be estimated by multiplying a chemical-specific TTR measured at a given time point by a pre-determined, appropriate task-specific hourly transfer rate (a.k.a. transfer factor or coefficient), as this is the conventional regulatory approach to estimating most types of reentry exposure from dermal contact with treated foliage.

Accordingly and per recent WHS practice, the default value of 6,000 μg/hr per body per lb AI applied was used instead as the reentry exposure for toddlers of 12 kg BW recreating on a treated lawn near the time of initial deposition. Given that the maximum application rate is 2.0 lb AI/acre for simazine used on turf (*vs*. on farm soil), their dermal reentry exposure near initial deposition was adjusted upward to 12,000 μg/hr. The upper-bound turf dermal uptake therefore would be 60 μg/kg/day [= (12,000 μg/hr, default value for 2 lb AI/acre) x (1 hr/day, duration of event) x (6% dermal absorption, Section III-2) x (12 kg BW, U.S. EPA, 1997)$^{-1}$)]. Note that the above default hourly exposure rate, which was adjusted for children's body surface area, was derived by averaging the nine (9) available hourly dermal exposures estimated for adults performing rather intensive Jazzercise type routines on turfs treated with collectively six (6) pesticides. This value represents a reasonable worst-case estimate in that the six pesticides were all in liquid formulation and that the hourly exposures were all from dermal exposures monitored within 3 hours post-application involving contact-intensive Jazzercise type routines and before the turf residues had more time to dissipate.

Given that the average half-life of the TTR was estimated to be 12 days (Rosenheck, 1999), a conservative *average* turf dermal uptake would be 40 μg/kg/day, or two-thirds of the upper-bound estimated above; that is, the initial TTR deposition (and hence the reentry exposure) would reduce by 33% at day 8 post-application (i.e., the shortest exposure period defined for intermediate-term). The basic notion here is that even though the method used in that study to measure TTR might not be up to what(ever) 'the standard' should be, it should not have a major effect on how the half-life on turf would be determined so long as the TTR were measured consistently each time, even with a less-than appropriate sampling method.

WHS staff (Dong *et al.*, 1994; Haskell *et al.*, 1998) had used a one-hour exposure time for a two- or three-year-old child playing outdoors. This default was partly based on a radon study by Rogers *et al.* (1986), in which children of age 6 to 15 were found to spend on average 1 hour per day *actually playing* outdoors; a two-year-old child is expected to play outdoors less frequent or in shorter duration than this. (Note that by *actually* playing here, it means the part of playing that would bring the child into *actual* dermal contact with the turf or soil residues.) The observation made by Rogers *et al.* was consistent with the survey conducted by ARB (Phillips *et al.*, 1991) on children's daily activity patterns. According to the ARB survey, children under age 12 would spend an average of about 1 hour per day playing in their yard (based on all children surveyed). WHS staff further contend that it is highly unlikely for any child to play *vigorously* (e.g., such as doing Jazzercise type routines) for more than 1 hour on treated lawns or soil on the day the treatment is made. Even if their area is to be treated with simazine in the morning, children would have at most a couple of hours left to play outdoors in that same *warm to hot* afternoon due to the 3- or 4-hour reentry restriction implicit in the label (i.e., until the sprays have dried).

According to the exposure assessment by Thongsinthusak *et al.* (1993b) for chlorpyrifos, it is expected that of the *total dermal* residues monitored from contact during Jazzercise in treated areas, roughly 14% is on the individual's hands. It is further expected that no more than 50% of the residues on a toddler's hands would be extracted through saliva and then be totally ingested by this child. These assumptions, which were also used in Dong *et al.* (1994), suggest that the acute ADD from hand-to-mouth by children in this age group would be 70 μg/kg/day [= (50% for hand-to-mouth as extractable through saliva) x (14% of the total dermal as for hand contribution) x (12,000 μg/hr, default value for 2 lb AI/acre) x (1 hr/day, duration of *actual* event) x (12 kg BW)$^{-1}$)]; and the subchronic or chronic ADD would be 46.7 μg/kg/day, or two-thirds of the acute as reasoned earlier (in relation to TTR's half-life).

For *object*-to-mouth exposure, U.S. EPA (2001b) used a daily ingestion rate of 25 cm^2 for children mouthing a small object (or a handful of turf) having a surface area ≤25 cm^2. Thus, from this exposure route, the oral intake at most would be 1.1 μg/kg/day [= (5% of applied residues as TTR) x (11 μg/cm^2 = 2.0 lb liquid AI/acre as the maximum applied rate, based on two-sided foliage surface) x (25 cm^2/day, the daily ingestion rate) x (12 kg BW)$^{-1}$]. This estimation was based on the assumption that the child would ingest all of the residues available on the defined surface of an object. Note that a child cannot perform both the hand-to-mouth from treated turf and the object-to-mouth from contaminated object at the same time. Therefore, to be health conservative, children's exposure from hand-to-mouth, rather than object-to-mouth, was emphasized in the present exposure assessment.

C. Aggregate Dose for Children

Table 19 lists the various individual route- and medium-specific upper-bound oral intakes and dermal uptakes of simazine residues estimated for two-year-old children playing on treated turf and on the soil underneath or around. Also included in this table is the upper-bound *aggregate* dosage which is the sum of all the estimated individual route-and medium-specific upper-bounds. These estimates may also be used as the upper-bounds for all other age groups including nonuser adult residents. This presumption is based on the expectation that the exposures to soil and foliar residues are less for the other age groups, in that their body mass is larger and their uptake and intake rates are presumably lower compared to those of a two-year-old. Although children younger than two years old have even a smaller body mass, their access to soil and turf residues is more limited since their outdoor activities are more restricted and more supervised.

For a two- to three-year-old child with normal mouthing behavior, the potential aggregate dosage from both treated turf and the soil around or underneath would be approximately 132.8 μg/kg/day [≅ 0.6 μg/kg/day from soil dermal uptake + 2.2 μg/kg/day from soil oral intake + 60 μg/kg/day from turf dermal contact + 70 μg/kg/day from turf hand-to-mouth]. For children in the same age group but with a pica problem, the total dosage would be roughly 152.6 μg/kg/day since the oral intake of soil residues would be 22 μg/kg/day, or about 10-fold higher than for children with normal mouthing behavior.

For both mouthing scenarios, the total dosage was likely overestimated, in that a child is unlikely to be exposed to the turf and soil residues during the same one hour of actual playtime. Also, for simplicity, the oral intake from object-to-mouth and the inhalation dose

Table 19. Estimates of Absorbed Daily Dosages (ADD, in µg/kg/day) of Simazine for Children and Adult Nonuser Residents[a]

Route and Medium[b]	Acute[c] ADD	Seasonal[c] ADD	Annual[d] ADD	Lifetime[e] ADD
Treated Turf				
dermal contact[f]	60.0	40.0	6.67	0.53
hand-to-mouth[g]	70.0	46.7	7.78	0.62
Treated Soil				
dermal uptake[h]	0.6	0.6	0.1	0.01
oral intake[i]	2.2 (22)	2.2 (22)	0.36 (3.6)	0.03 (0.3)
Total (Aggregate)[j]	132.8 (152.6)	89.5 (109.3)	14.9 (18.2)	1.2 (1.5)

[a] as discussed in the text, these estimates may be used to represent the upper-bound for all other age groups including nonuser adults, given that the exposures of these other age groups were expected to be much less primarily due to their larger body mass and the lower uptake and intake rates assumed for them; *in parentheses for the oral intakes and total dosages are for children with pica*.

[b] as discussed in the text, inhalation exposure to simazine and oral intake from object-to-mouth were considered minimal compared to those from other routes and media, and hence not included here.

[c] the calculated ADD was mainly for acute or short-term exposure; but for lack of data on timed soil degradation and on average reentry time, it was also used here as a conservative average or seasonal ADD (SADD) for intermediate-term exposure.

[d] annual or annualized ADD (AADD) = SADD x (2 months per year) x (12 months in a year)$^{-1}$; the 2 months for annual exposure frequency was based on the presumption that children would spend at most 2 (e.g., summer) months per season as well as per year outdoors playing regularly (for about 1 hour of actual contact per day) when the turf and soil residues could be at a level of concern.

[e] lifetime ADD = LADD = AADD x (~6 child years of exposure) x (~75 years in a lifetime)$^{-1}$.

[f] ADD from turf dermal contact = [(12,000 µg/hr, default value for 2 lb AI/acre) x (1 hr/day, duration of actual dermal contact) x (6% dermal absorption, Section III-2) x (12 kg BW = body weight, U.S. EPA, 1997)$^{-1}$)].

[g] ADD from turf hand-to-mouth = [(50% for hand-to-mouth as the portion extractable via saliva) x (14% of total dermal exposure for hand contribution) x (12,000 µg/hr, default value for 2 lb AI/acre) x (1 hr/day, duration of actual dermal contact) x (12 kg BW)$^{-1}$)], as discussed in the text.

[h] ADD from soil dermal uptake = [(27 mg/kg upper-bound soil level) x (1.5 mg/cm^2 upper-bound soil-to-skin adherence per 1 hr event/day) x (3,000 cm^2 BSA) x (6% dermal absorption) x (12 kg BW)$^{-1}$], where BSA = body surface area first based on the formula [BSA = (4 x BW)/(BW + 90)] by Costeff (1966) and then taking 55% as the exposed area responsible for skin-soil loading (e.g., as used in Thompson *et al.*, 1992); the upper-bound soil level was a theoretical maximum based on 3 applications made at a maximum label rate within 6 months (*see* the text for further discussion).

[i] ADD from soil oral intake = [(27 mg/kg upper-bound soil level) x (1,000 mg/day soil ingestion rate for normal mouthing behavior) x (100% default oral absorption) x (12 kg BW)$^{-1}$)]; the upper-bound soil ingestion rate was adopted from that provided in the *Exposure Factor Handbook* by U.S. EPA (1990, 1997) and used earlier by Dong *et al.* (1994); the handbook also provides an upper-bound ingestion rate of 10,000 mg/day for children with pica.

[j] total (aggregate) ADD = [(ADD from turf dermal contact) + (ADD from turf hand-to-mouth) + (ADD from soil dermal uptake) + (ADD from soil oral intake)].

were excluded from this aggregation because again they were deemed inconsequential compared to the dosages received from the other (major) routes of exposure. As noted earlier, inhalation exposure is expected to be minimal in that the vapor pressure of simazine is fairly low (Table 1). And children are not expected to perform both *hand*-to-mouth (from treated turf or soil) and *object*-to-mouth at the same time. As estimated above, a young child's exposure from hand-to-mouth is about 60 times (70 *vs*. 1.1 μg/kg/day) greater than from object-to-mouth. In other words, it is not necessary to include the exposure from object-to-mouth in calculating the aggregate dose for a worst-case exposure when the same child could put his or her contaminated hand into his or her mouth instead of another object.

For lack of data on soil degradation and on average reentry time, the aggregate dosages from *average* exposure for seasonal or chronic exposure for children with pica or normal mouthing behavior were based on the same upper-bound soil dermal uptake and soil intake estimates as used for acute exposure. Accordingly, the aggregate dosages from average exposure would be 109.3 and 89.5 μg/kg/day for children with pica and normal mouthing behavior, respectively (Table 19).

D. Inhalation Exposure for By-standers

In estimating the aggregate exposure earlier for nonuser residents in general, but more for two-year-old children in particular, the inhalation component was considered repeatedly to be inconsequential when compared to their dermal uptake and oral intake of turf and soil residues. Actually, such an expectation can be justified more quantitatively or numerically from another angle as follows.

According to the parameters set forth by WHS (Donahue, 1996), an acute ADD of 0.3 μg/kg BW per day is considered to be biologically insignificant for pesticides without applicable toxicity data. This default asserts that the acute air concentration of concern, for simazine or any other pesticide, is 0.5 μg/m^3 or higher given that the inhalation rate for a two-year-old is defaulted to approximately 0.3 m^3/hr, or 7.2 m^3 in 24 hours (Andrews and Patterson, 2000). That is, (ADD of 0.3 μg/kg BW/day, acceptable safe intake dosage) = [(0.5 μg/m^3, critical air level) x (7.2 m^3/day, daily inhalation rate) x (100% maximum inhalation absorption rate, Section III-2) x (12 kg BW for two-year-olds, U.S. EPA, 1997)$^{-1}$]. Two-year-olds were used in the present exposure assessment to represent the worst case for inhalation exposure in a residential area because they have the largest inhalation rate per unit of BW in all age groups, except for infants who nevertheless would not spend as much time outdoors as the two-year-olds would.

The above critical air concentration (i.e., 0.5 μg/m^3) assures that both the ambient and the onsite air concentrations of simazine monitored by ARB (1999) were not of significant health concern and hence were not specifically addressed in this exposure assessment document. As noted in Subsection IV-1, the highest ambient air concentration observed in the ARB study was less than 0.02 μg/m^3. And the highest air concentration observed at the application site was less than 0.19 μg/m^3 in 1 hour following a groundboom spray at 3.6 lb AI/acre. After adjustment for the maximum application rate of 5.0 lb AI/acre (as listed in Table 5), this highest one-hour onsite air level would be <0.3 μg/m^3, which is still substantially lower than the critical air level of 0.5 μg/m^3 defaulted for an acute 24-hour inhalation exposure.

Note that the above one-hour estimate (i.e., <0.3 μg/m^3), upon adjustment for the maximum application rate, should be considered as the maximum air concentration expected to occur at any application site for simazine in that the AI is a nonvolatile herbicide. Chemigation is the only other ground spray alternative for simazine application to farm soil. Actually when herbicides are applied through a sprinkler system, the process is more properly referred to as herbigation. This system is used primary as a long spray boom. Therefore, herbigation is considered to have similar effects of air contamination in the spray zone as groundboom spray has, especially when the pesticide is a nonvolatile compound. Nonvolatile residues tend to settle (dissipate) rapidly immediately following a spray. In other words, the simazine residues generated from application to one section of the field are not likely to have the opportunity to be accumulated in the air with those generated from spray to another section. Also, at any given time of the day, a bystander can only be near one edge of a treated field.

The above argument appears to have been undermined somewhat, in that no air monitoring data for aerial application were available for use and thus only those for ground application were considered instead. Nonetheless, the PUR data in Table C-3 (Appendix C) suggest that the monthly usage of simazine (and hence monthly applications as well) via aerial spray is limited in California. Yet more importantly, as shown in Table 19, the acute aggregate ADD estimated from all other (major) routes of exposure was 133 μg/kg/day for a two-year-old child with normal mouthing behavior. This implies that until or less the inhalation exposure involved reaches around 3 μg/kg/day (instead of 0.3 μg/kg/day), or roughly 2% of the aggregate ADD estimate, it may be considered inconsequential. This in turn implies that as per earlier estimation for ground application, the significant air level should be (set at) 5 μg/cm^3, not 0.5 μg/cm^3. Although it may not be improbable, the chance is not high for the onsite air levels from aerial spray to be more than 10- or 15-fold greater than those (with the highest observed being <0.3 μg/cm^3, as noted above) from ground application.

In short, based on the air monitoring data available to WHS to this date, there is no reason to believe that the inhalation exposure to simazine is significant for residents or bystanders.

VI. EXPOSURE APPRAISAL

1. Use of Defaults and Surrogate Data

Handler Exposure. PHED (1995) has a considerable number of limitations as a surrogate database. It combines measurements from worker exposure studies conducted using different protocols, different analytical methods, and different residue detection limits. Most dermal exposure studies in PHED used the patch dosimetry method of Durham and Wolfe (1962), which requires residues measured on small patches placed on different regions of the body to be extrapolated to estimate exposure to that region. In some of these studies, patches were placed on a few body regions only, such as only the hands, arms, head, and face. As a result, the estimates of dermal exposure for various body regions are often based on different sets of replicates. For some scenarios, the number of matching observations in PHED is so small that the estimate is not reliable. Due to the degree of uncertainty so inherent in the PHED data, WHS has opted to approximate the UCL for the exposure statistics in an attempt to increase the confidence in the exposure estimates used.

The limitations with PHED are more than statistical in nature. The exposure data in PHED were graded for laboratory and field sample recoveries. Grades A and B presumably represent high quality data, with laboratory and field recoveries generally greater than 80 and 50%, respectively, for the set of observations considered. Grade C represents moderate data quality, with laboratory and field recoveries ranging from 70 to 120% and 30 to 120%, respectively, for the set of observations involved. In line with the criteria set forth by U.S. EPA (1998), the current position of the WHS scientific staff is that the PHED subsets with grade A or B data and a minimum of 15 observations are considered to provide high confidence in data quality. Those PHED subsets including grade C data are considered to provide moderate confidence.

As shown in Appendices B-1 through B-7, 5 of the 7 PHED subsets include grade C data. The two subsets with grade B data or better are for mixer/loaders handling flowable (i.e., liquids) under open pouring and for human flaggers guiding aerial liquid sprays. Also shown in these B-series appendices are three PHED subsets that have less than 20 observations for dermal (excluding hand) exposure, meaning that a multiplier of 5 or greater was used to generate the upper-bound dermal ADD for the three subsets. The three PHED subsets with fewer than 20 observations (replicates) were for aerial applicators spraying liquid simazine and M/L/applicators using either a high-pressure or backpack sprayer.

As footnoted in Tables 15 and 17, for exposure estimates from the non-PHED surrogate data (e.g., those for use of simazine via low-pressure handwand or handgun sprayers), the acute and seasonal ADD were not based on the multipliers derived per interim guidance (Frank, 2007). This is because while the multipliers are needed, they need to be so derived (assumed) only when the associated standard deviation (and hence the associated coefficient of variation) is not known. For those exposure estimates in Tables 15 and 17 not derived from PHED, the *average* ADD were used as is; and the acute or short-term ADD were calculated as the average ADD + 2 standard deviations (SD). This is because, once again, neither a 90% UCL on the 95th percentile nor a 90% UCL on the mean should be calculated using the same formula as used for calculating the multipliers for the PHED type data (*see* Frank, 2007), unless a lognormal distribution could or should be assumed for the data involved. Otherwise, for chemical-specific exposure data of acceptable quality tending to follow a normal distribution, the arithmetic mean + 2 SD is considered to be a fair or sufficient estimate of the actual population's 95th percentile.

Default Usage. The dose estimates for handlers were calculated under the premise that exposure is linearly proportional to the amount of pesticide handled. It is fair to say that this is unlikely the case where the amount of pesticide applied is outside a practical range. To put it another way, a large amount of material used in a day's work can be handled in a number of ways, depending on how the product is packaged or formulated and what type of mixing, loading, or application equipment/method is used.

The caution for consideration of a practical range is not without merits. U.S. EPA (2001b) uses 350 acres per day for aerial application to lower-acre (e.g., row) crops, justifying that the estimate was based on the PHED application data normalized to an 8-hour day. Yet their daily acreage of 1,200 assumed for aerial application to higher-acre crops (e.g., corn, cotton, wheat, alfalfa) was also based on an 8-hour workday. Thus, if the exposure rate were based on hours worked, instead of amount of pesticide handled, then in this case it would make no difference whether the daily acreage is 350 or 1,200 for aerial application, as daily *exposure* would be unaffected by this acreage difference. Yet despite such an argument, in general exposure rate based on amount of pesticide handled is still deemed to be more practical. This is because exposure rate based on work time is less reliable, as it is more difficult to monitor the actual time spent in a specific task than to monitor the amount of pesticide used.

Data from two biomonitoring studies, as summarized in Ross and Driver (2005), further support readily as well as empirically the caution on practical range. In one study on *airblast* mixer/loaders (Honeycutt and DeGeare, 1994), the daily dosage was estimated as 4.7 μg/kg for the workers handling 74 lb of chlorpyrifos liquid under an open-pour system. In another study on *aerial* mixer/loaders wearing *less* personal protective equipment (Knuteson *et al.*, 1999), the daily dosage was estimated as 1.2 μg/kg for handling 400 lb (i.e., 5.4 times more) of the same pesticide liquid while using a similar type of system for mixing/loading. Accordingly, the chemical-specific exposure *rates* calculated from these two studies are *4.4 μg per lb of (chlorpyrifos) AI handled* [= (4.7 μg/kg) x $(74\ \text{lb})^{-1}$ x (70 kg)] and *0.21 μg per lb of AI handled* [= (1.2 μg/kg) x $(400\ \text{lb})^{-1}$ x (70 kg)], respectively, for airblast and aerial mixer/loaders each having a body weight of 70 kg. It thus appears that beyond a certain range, handler exposure is not necessarily linearly proportional to the amount of pesticide handled, at least not when different types of mixing/loading equipment are used. One possible explanation for the nearly 21-fold exposure rate difference (i.e., 4.4 μg/lb handled for mixing/loading for airblast *vs.* 0.21 μg/lb handled for mixing/loading for aerial) observed between the above two studies is that, perhaps due to the larger or more advanced mixing/loading tanks employed, actually fewer loadings might have been required for the aerial spray than for the airblast (ground) application (thus resulting in shorter exposure duration or contact).

The defaults used for maximum daily acreage in pesticide exposure assessment thus must be treated with the above caution in mind. It was also for this reason that the default was capped and rounded to 600 acres per day for aerial application even though as many as 640 acres from a unique single application of simazine in California counties were reported (as noted in Subsection V.1.A).

It should be noted here that the way in which the PUR data were used earlier for aerial spray (as discussed in Subsection V.I.A) is not directly applicable for groundboom application, as up to some 600 acres were also reported to have been covered per use number for *ground* spray. Apparently, *multiple* groundboom tractors were used on the same day for such a large operation. As stated earlier, the maximum daily acreage used for groundboom application was 100. This can be justified with the following numerical argument.

As often observed by the WHS field teams, each pass (spray line) for ground spray to cotton or corn is at most 36 feet wide since the booms in the center and on the left and the right side together cover 9 rows each of 3 to 4 feet wide. Each one-mile long pass thus would cover 4.4 acres of the crop. This in turn would require 23 passes to cover 100 acres. With an average tractor speed of 4 MPH, or 1 pass (mile) per 15 minutes (excluding the time for turning the tractor around for the next pass), it would require 5.75 hours (= 345 minutes = 23 passes x 15 minutes/pass) to spray 100 acres. It would also require at least 6 reloadings of the spray solution per tractor with a typical tank size of 300 to 350 gallons, since simazine should be applied at a minimum of 20 gallons per acre. Therefore, even at the rate of 1 loading per 15 minutes (including the time for bringing the tractor to the reloading facility, etc.), it would take 1.5 hours to complete all 6 reloadings required for 100 acres per tractor. In short, all together each tractor (applicator) would take at least 7 *straight* hours to complete 100 acres, excluding the time spent in cleaning the boom equipment after its use for the day.

2. Exposure Assessment by U.S. EPA

U.S. EPA (2005) completed their occupational and residential exposure assessment in a separate document a year ahead of the release of their RED for simazine. In that federal assessment document, they included a total of 32 exposure scenarios for occupational handlers. If the wettable powder and (nonwater-dispersible) granular formulations were excluded, which are not currently registered in California (or with U.S. EPA), then their occupational handler scenarios would come close to the total of 14 potential scenarios considered in the present exposure assessment by WHS.

One small difference in the number of handler exposures assessed between the two agencies is that U.S. EPA separated handlers into mixer/loaders only and applicators only for the following applications: (1) liquid spray for lawn care with a handgun; and (2) liquid for rights-of-way. The present exposure assessment nonetheless maintained that these types of applications almost never call for a daily operation larger enough that a person should do the applying alone for over 7 or 8 hours. That is, there is no reason to believe that this person cannot mix/load the herbicide product by himself or herself prior to applying the same.

Still another small difference is that the present exposure assessment did not consider rights-of-way type applications necessarily as a separate use scenario. This is because the use scenarios considered here were thought to be adequate to cover all of the application methods typically employed for this type of site-specific application, at least for exposure estimation purposes. Boom sprayer, herbigation, handheld sprayer, and their variations (e.g., straight stream nozzles, off-center nozzles) are normally used for rights-of-way applications.

Simazine is a herbicide supposedly applied to weeds or soil (including orchard and vineyard floors) directly for control of weed growth. Its product labels specifically caution against crop injury. It was based on this premise that the present exposure assessment considered the field reentry exposures all to be minimal. This position is consistent with the assessment results presented in the U.S. EPA document, which concluded that reentry tasks were a risk concern only for those *both* with a higher dermal transfer rate (TR) *and* performed within the first 48 hours post-application. According to U.S. EPA (2005), those reentry tasks considered to have a high enough TR value of concern included pruning, training, or staking Christmas tree plantings and transplanting, harvesting, or weeding turfgrass on sod farms. The present WHS exposure assessment took the position that while the (relatively high) TR values that U.S. EPA used for a few of these reentry tasks are questionable, in practice none of these tasks is likely to be performed within the first 48 hours post-application. In addition, the PUR data (Table 3) clearly support the presumption that in reality, the use of simazine on Christmas trees and the kind is minimal.

Weed treatment is primarily a prophylactic measure, which is most effective if it is applied prior to weed emergence or after removal of weed growth. Therefore, it is highly unlikely that (most) growers would schedule their pruning activity or the kind within the first couple of days following weed treatment with a herbicide. In fact, the likelihood is extremely rare that growers would transplant any turfgrass that has *just* been treated with a herbicide, considering that an important criterion for turf transplanting is to select good quality turf *free* from serious weeds, insects, diseases, or nematode damage. Furthermore, herbicide application is not at all an inexpensive treatment that would afford growers to risk any soil or residue disturbance by such site trafficking activity as pruning, training, topping, and staking that nonetheless could always be performed at least a few days earlier or later. In addition, simazine needs to be watered in to be effective, in which case the herbicide's residues on turf or foliage should be minimal.

For residential exposure, U.S. EPA (2005) assessed the health risks separately for three age groups engaging in three major categories of reentry activities following treatment with either granular or liquid simazine. Their scenario categories included toddlers, young children, and adults from, where applicable, high contact activities (e.g., gardening, playing), hand-to-mouth, object-to-mouth, mowing, golfing, and incidental soil ingestion. U.S. EPA's overall health risk finding for this type of residential exposures was that none of the scenarios would pose a concern.

3. Estimation of Annual and Lifetime Exposures

As discussed earlier, there are no pesticide use data available for the direct projection of exposure frequency for individual workers in California. The PUR data cannot be truly used to project the temporal patterns for handlers exposed to simazine because the pesticide is used primarily for control of weed growth. The use of herbicides has a prime season not well reflected in the PUR data which can only be as descriptive as summarizing each AI's usage by crop/site, county, pounds applied, number of applications made, acres treated, grossly-defined application method (i.e., simply as aerial *vs*. ground), etc., but not by weed growth in any way. The two-month exposure period assumed throughout for all handler groups (and bystanders as well) included in the present exposure assessment is considered to be an adequate estimate, for reasons given in Appendix C.

4. Use of Pharmacokinetics and Toxicity Data

Like in most pesticide exposure assessments, dosage is expressed here as a single static value both in worker exposure and in oral studies on animal or human toxicity. However, the rates of dermal absorption and dermal acquisition are often seen or expected to be lower than the rates of oral absorption and oral acquisition in animals used for toxicity studies. In short, the dose through the nonbolus dermal route is likely to be less potent than the same amount administered orally. This factor was discussed more extensively in Dong and Haskell (2000) and in Ross *et al.* (2000).

5. Exposure for Swimmers in Surface Water

As noted earlier, an acute ADD of 0.3 μg/kg BW is considered by WHS to be biologically insignificant for pesticides without applicable toxicity data (Subsection V-3.D). And the California's public health goal for simazine in drinking water was set at 4 μg/L (as stated in the Introduction). This public health goal is the same as the national Maximum Contaminant Level (MCL) that U.S. EPA (2009) set for simazine.

Because of such a low MCL set for simazine and the fact that the other EADs (e.g., that for carbaryl) have already estimated the potential exposure for swimmers in surface water, WHS is now able to conclude easily that such an exposure scenario will not merit consideration unless either the skin permeability coefficient K_p for the pesticide under assessment is greater than 0.03 cm/hr or the no-observed-effect-level (NOEL) of concern is approaching the nano-grams scale. If the NOEL were indeed down to the nano-grams, then the exposure to the pesticide for swimmers would be the least of California's public health concern inasmuch as the other subpopulations in the state would then be at much greater risks to simazine. The K_p for simazine is 0.003 cm/hr, as calculated from a K_{ow}-based algorithm given by U.S. EPA (2004) along with the octanol-water partition coefficient (K_{ow}) value listed in Table 1 in this document. And the available water monitoring data (as presented in Subsection IV-5) support the expectation that the simazine levels in surface and ground water in California are below the MCL.

6. Variation in Exposure-Related Factors among Products

It is of note that, of the 13 products actively-registered in California as of late April 2013 (as those listed in Table 2), only the flowable product Sim-Trol 4L (Oxon Italia) and the two dry-flowable products Sim-Trol 9DF and Sim-Trol 90DF allow aerial sprays (where specified in the use directions) and have the maximum (aerial or ground) spray rate set at 5 lb AI per acre of grape vineyard (actually 4.8 lb AI/acre). For all other simazine products, the maximum spray rate is 4 lb AI per acre. In addition, unlike the other dry-flowable or water-dispersible products, Sim-Trol 9DF and Sim-Trol 90DF do not require mixer/loaders to wear an approved respirator or coveralls (over normal work clothes). As the data on the calculated ADD in Table 14 suggest, the various ADD estimates calculated for mixer/loaders handling dry-flowable (in an agricultural setting) could be reduced by roughly 90% due to the additional PPE required (inasmuch as the contributions from the hand and the inhalation component were comparatively negligible). Furthermore, for those simazine products setting the maximum spray rate at 4 lb AI/acre, instead of 5 lb AI/acre, the ADD estimates could be (further) reduced by 20%.

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VIII. APPENDICES

Appendix A: Scoping of Potential Exposure Scenarios for Simazine

As of late April 2013, a total of 13 simazine-containing products were actively registered in California (as summarized in Table 2 in Section II of this exposure assessment document). A thorough review of the registered labels for these 13 products reflected 8 major categories of potential exposure scenarios as follows: (1) mixing/loading for aerial spray; (2) mixing/loading for groundboom spray; (3) mixing/loading for chemigation/microsprinkler type irrigation; (4) spraying with aerial equipment; (5) spraying with groundboom equipment; (6) flagging for aerial spray; (7) mixing/loading and applying (M/L/A) with handheld spray equipment; and (8) nonuser residents as well as bystanders.

Handheld equipment for M/L/A may include low-pressure handwand or handgun controlled sprayers and, occasionally, backpack sprayers or high-pressure handwand/handgun sprayers.

In the present assessment for residents, nonuser exposure to simazine was limited to oral intake and dermal uptake of soil and turf residues by two-year-old children, who represent the worst case for all age groups including adults. Exposure to drift is not expected given that simazine should be watered into the soil and is a nonvolatile compound.

The following observations and considerations strongly support the expectation that reentry exposures are negligible for fieldworkers. As with all other herbicides, simazine is to be used with care to avoid crop injury; and no application is allowed in fields where crops reach the harvest stage. According to the product labels, turfgrass for sod is not to be treated if it is to be cut or lifted within 30 days. The herbicide also may not be used on golf greens. Simazine can take its herbicidal effects only when it is absorbed through the roots of weed seedlings. Therefore, it is often a good practice to remove prunings and trash from the crop floor before any spraying is to take place; in other words, the amount of debris that can be contaminated and touchable is minimal. Despite the fact that workers may enter a field to irrigate or to scout a treated area, their dermal contact is minimal in that the residues are primarily in the soil, or at most on turfgrass or weeds not taller than angle high. After all, simazine may not be applied to weeds when they exceed 1.5 inches. Reentry exposure from mowing was considered negligible due to the minimal dermal contact with treated *weeds* (*see* further discussion in Subsection V-3 in the text). The product labels now also advise users "*not to apply simazine where the water table (groundwater) is close to the surface and where the soils are very permeable*." Given that simazine has a very low vapor pressure (Table 1 in the text), inhalation exposure to airborne residues from reentry is expected to be inconsequential.

When application methods were further subdivided and product formulation must also be considered, there were a total of 14 subcategories of potential exposure scenarios determined as pertinent to simazine used in either the agricultural or the non-agricultural setting. These 14 scenarios are listed in Table A-1 below, and actually are the sum of those listed in Tables 5 through 8, Table 16, Table 18, and Table 19, all presented in Section V (i.e., all of those considered in the Exposure Assessment section).

Table A-1. Potential Major Exposure Scenarios Determined as Related to Simazine Used in Either the Agricultural or the Non-Agricultural Setting

Formulation	Application Method/Equipment	Work Group/Activity
	I. Agricultural Use	
Liquid[a]	aerial	applicator
	groundboom	applicator
	aerial	flagman
Dry flowable[b]	aerial	mixer/loader
	groundboom	mixer/loader
Flowable	chemigation/microsprinkler	mixer/loader
	low-pressure handwand	mixer/loader/applicator
	high-pressure handwand	mixer/loader/applicator
	backpack sprayer	mixer/loader/applicator
	II. Non-Agricultural Use	
Flowable	low-pressure handwand	homeowner user
	low-pressure handwand	mixer/loader/applicator
	high-pressure handwand	mixer/loader/applicator
	backpack sprayer	mixer/loader/applicator
All formulations	all types of equipment[c]	nonusers (primarily children)

[a] as in all spray solutions, such as from dry flowable, water-dispersible granule, and flowable.

[b] including water-dispersible granule with respect to the mixing/loading involved.

[c] equipment used in the agricultural setting was also considered (e.g., for exposure due to drift, which was concluded to be negligible).

Appendix B-1: Aerial Applicator, Liquids, Open Cockpit

Table 17-1. Description of PHED subsets for Scenario 17[a]

Parameter	Specifications used to generate subsets [a]	Actual characteristics of resulting subsets
Data Quality Grades[b]	A,B,C	A,B,C
Liquid Type	Not specified	All emulsifiable concentrate
Solid Type	Exclude granular	none
Application Method	Fixed- or rotary-wing	All fixed-wing
Cab Type	Open Cab or Closed Cab with Open Window	Open Cab or Closed Cab with Open Window

[a] subsets of Applicator data in the Pesticide Handlers Exposure Database (PHED). Parameter descriptions are from screens displayed in the PHED program.
[b] data quality for Dermal Uncovered, Dermal Covered, and Hand were Grade A or C; Airborne data were Grade B or C. Data quality grades are defined in the text and in Versar (1992).

Figure 17-1. Summary of results from the Pesticide Handlers Exposure Database (PHED) Subset for Scenario 17[a]

SUMMARY STATISTICS FOR CALCULATED DERMAL EXPOSURES
SCENARIO: Long pants, long sleeves, gloves

PATCH LOCATION	MICROGRAMS PER LB AI SPRAYED Mean	Coef of Var	Geo. Mean	Obs.
HEAD (ALL)	4.212	118.2574	1.2438	10
NECK.FRONT	.414	143.6715	.1169	10
NECK.BACK	.3124	139.1485	.0741	10
UPPER ARMS	8.5554	109.6232	5.7532	10
CHEST	6.3065	158.1987	2.1395	17
BACK	8.7497	141.5614	3.131	17
FOREARMS	2.7901	131.7516	1.1744	17
THIGHS	9.55	157.4126	3.4718	13
LOWER LEGS	7.4494	138.0769	3.3312	10

Subset Name:
S17DERMAL.APPL

[a] subset criteria included actual and estimated head patches. Of the 10 head observations, 7 were actual and 3 were estimated from nearby patches (Versar, 1992).

Table 17-2. PHED data from dermal, hand, and inhalation subsets[a]

Exposure Category	Exposure (µg/lb AI handled)	Replicates in subset	Short-Term Multiplier[b]	Long-Term Multiplier[b]
Dermal (non-hand)[c]	52.2	10[d]	6	2
Hand (with gloves)	9.63	9	6	2
Inhalation	0.573	14	5	2

[a] results from subsets of Applicator data in the Pesticide Handlers Exposure Database (PHED). Results rounded to three significant figures.
[b] multipliers are explained in the text and in Frank (2007).
[c] dermal total includes addition of default feet value of 0.52 x (value for lower legs); ratio of feet/lower leg surface area (U.S. EPA, 1997).
[d] median number of replicates was used in determining subset multipliers.

Table 17-3. Values Used in Scenario 17 Exposure Calculations[a]

	Short-Term Exposure		Long-Term Exposure	
Total Dermal (with gloves)	6(52.2) + 6(9.63) =	371 µg/lb AI handled	2(52.2) + 2(9.63) =	124 µg/lb AI handled
Total Dermal (no gloves)[b]	6(52.2) + 60(9.63) =	891 µg/lb AI handled	2(52.2) + 20(9.63) =	297 µg/lb AI handled
Inhalation	5(0.573) =	2.86 µg/lb AI handled	2(0.573) =	1.15 µg/lb AI handled

[a] values from Table 17-2. Results rounded to three significant figures.
[b] gloves assumed to provide 90% protection (Aprea *et al.*, 1994); exposure of bare hands is calculated as ten times exposure of gloved hands.

Appendix B-2: Groundboom Applicator, Open Cab

Table 11-1. Description of PHED subsets for Scenario 11[a]

Parameter	Specifications used to generate subsets [a]	Actual characteristics of resulting subsets
Data Quality Grades[b]	A,B	A,B,C
Liquid Type or Solid Type	Not specified	Emulsifiable concentrate or wettable powder
Application Method	Groundboom, Truck or Tractor	Groundboom, Tractor
Cab Type	Open Cab or Closed Cab with Open Window	Open Cab or Closed Cab with Open Window

[a] subsets of Applicator data in the Pesticide Handlers Exposure Database (PHED). Parameter descriptions are from screens displayed in the PHED program.
[b] data quality grades for Airborne, Dermal Uncovered, Dermal Covered and Hand are all Grade A or B, with the exception of one dermal replicate that has Dermal Uncovered Grade C (Dermal Covered for that replicate is Grade B). Data quality grades are defined in the text and in Versar (1992).

Figure 11-1. Summary of results from the Pesticide Handlers Exposure Database (PHED) subset for Scenario 11[a]

SUMMARY STATISTICS FOR CALCULATED DERMAL EXPOSURES

SCENARIO: Long pants, long sleeves, no gloves

Subset Name: S11DERMAL.APPL

PATCH LOCATION	MICROGRAMS PER LB AI SPRAYED Mean	Coef of Var	Geo. Mean	Obs.
HEAD (ALL)	2.7891	136.1192	1.0464	33
NECK.FRONT	1.5763	167.9503	.3296	23
NECK.BACK	1.0063	173.5765	.2335	29
UPPER ARMS	1.6914	88.749	1.1637	32
CHEST	1.7581	98.5154	1.1329	42
BACK	3.0175	233.2361	1.3959	42
FOREARMS	2.7301	419.1055	.564	32
THIGHS	3.1255	185.5703	1.1806	33
LOWER LEGS	2.1148	172.3425	.7466	35

[a] subset criteria included actual and estimated head patches. Of the 33 head observations, all were actual.

Table 11-2. PHED data from dermal, hand, and inhalation subsets for Scenario 11[a]

Exposure Category	Exposure (µg/lb AI handled)	Replicates in subset	Short-Term Multiplier[b]	Long-Term Multiplier[b]
Dermal (non-hand)[c]	20.9	33[d]	4	1
Hand (no gloves)	45.6	29	4	1
Inhalation	1.18	22	4	1

[a] results from subsets of Applicator data in the Pesticide Handlers Exposure Database (PHED). Results rounded to three significant figures.
[b] multipliers are explained in the text and in Frank (2007).
[c] dermal total includes addition of default feet value of 0.52 x (value for lower legs); ratio of feet/lower leg surface area (U.S. EPA, 1997).
[d] median number of replicates was used in determining subset multipliers.

Table 11-3. Values Used in Scenario 11 Exposure Calculations[a]

	Short-Term Exposure	Long-Term Exposure
Total Dermal (with gloves)[b]	4(20.9) + 0.4(45.6) = 102 µg/lb AI handled	1(20.9) + 0.1(45.6) = 25.5 µg/lb AI handled
Total Dermal (no gloves)	4(20.9) + 4(45.6) = 266 µg/lb AI handled	1(20.9) + 1(45.6) = 66.5 µg/lb AI handled
Inhalation	4(1.18) = 4.72 µg/lb AI handled	1(1.18) = 1.18 µg/lb AI handled

[a] values from Table 11-2. Results rounded to three significant figures.
[b] gloves assumed to provide 90% protection (Aprea *et al.*, 1994); exposure of gloved hands is calculated as one tenth exposure of bare hands.

Appendix B-3: Human Flaggers, Liquids

Table 7-1. Description of PHED subsets for Scenario 7[a]

Parameter	Specifications used to generate subsets [a]	Actual characteristics of resulting subsets
Data Quality Grades[b]	A,B	A,B
Liquid Type or Solid Type	Not specified	Emulsifiable concentrate or dry flowable
Application Method	Fixed- or rotary-wing	All rotary-wing

[a] subsets of Flagger data in the Pesticide Handlers Exposure Database (PHED). Parameter descriptions are from screens displayed in the PHED program.
[b] data quality for Dermal Uncovered and Dermal Covered are all Grade A; Airborne and Hand data are all Grade A or B. Data quality grades are defined in the text and in Versar (1992).

Figure 7-1. Summary of results from the Pesticide Handlers Exposure Database (PHED) subset for Scenario 7[a]

SUMMARY STATISTICS FOR CALCULATED DERMAL EXPOSURES
SCENARIO: Long pants, long sleeves, gloves

PATCH LOCATION	MICROGRAMS PER LB AI SPRAYED Mean	Coef of Var	Geo. Mean	Obs.
HEAD (ALL)	11.3028	127.5702	5.6188	18
NECK.FRONT	.9533	134.3334	.5146	18
NECK.BACK	1.4111	215.8529	.4931	18
UPPER ARMS	3.9285	195.1025	.8284	28
CHEST	5.1065	188.8378	1.0384	26
BACK	5.1065	188.8378	1.0384	26
FOREARMS	1.802	179.5283	.3837	28
THIGHS	4.0404	308.6996	.9165	26
LOWER LEGS	2.448	305.6618	.612	28

Subset Name:
S7DERMAL.FLAG

[a] subset criteria included actual and estimated head patches. Of the 18 head observations, all were actual.

Table 7-2. PHED data from dermal, hand, and inhalation subsets for Scenario 7[a]

Exposure Category	Exposure (µg/lb AI handled)	Replicates in subset	Short-Term Multiplier[b]	Long-Term Multiplier[b]
Dermal (non-hand)[c]	37.4	26[d]	4	1
Hand (no gloves)	5.97	30	4	1
Inhalation	0.200	28	4	1

[a] results from subsets of Flagger data in the Pesticide Handlers Exposure Database (PHED). Results rounded to three significant figures.
[b] multipliers are explained in the text and in Frank (2007).
[c] dermal total includes addition of default feet value of 0.52 x (value for lower legs); ratio of feet/lower leg surface area (U.S. EPA, 1997).
[d] median number of replicates was used in determining subset multipliers.

Table 7-3. Values Used in Scenario 7 Exposure Calculations[a]

	Short-Term Exposure	Long-Term Exposure
Total Dermal (with gloves)	4(37.4) + 0.4(5.97) = 152 µg/lb AI handled	1(37.4) + 0.1(5.97) = 38.0 µg/lb AI handled
Total Dermal (no gloves)[b]	4(37.4) + 4(5.97) = 173 µg/lb AI handled	1(37.4) + 1(5.97) = 43.4 µg/lb AI handled
Inhalation	4(0.200) = 0.800 µg/lb AI handled	1(0.200) = 0.200 µg/lb AI handled

[a] values from Table 7-2. Results rounded to three significant figures.
[b] gloves assumed to provide 90% protection (Aprea *et al.*, 1994); exposure of gloved hands is calculated as one tenth exposure of bare hands.

Appendix B-4: Mixer/Loader, Open System, Liquids

Table 5-1. Description of PHED subsets for Scenario 5[a]

Parameter	Specifications used to generate subsets [a]	Actual characteristics of resulting subsets
Data Quality Grades[b]	A,B	A,B
Liquid Type	Emulsifiable concentrate, aqueous suspension, microencapsulated, solution, or undiluted liquid	Emulsifiable concentrate, solution
Mixing Procedure	Open	Open

[a] subsets of Mixer/Loader data in the Pesticide Handlers Exposure Database (PHED). Parameter descriptions are from screens displayed in the PHED program.
[b] data quality for Dermal Uncovered, Dermal Covered and Airborne are all Grade A or B; Hand data are all Grade A. Data quality grades are defined in the text and in Versar (1992).

Figure 5-1. Summary of results from the Pesticide Handlers Exposure Database (PHED) dermal subset for Scenario 5[a]

SUMMARY STATISTICS FOR CALCULATED DERMAL EXPOSURES
SCENARIO: Long pants, long sleeves, gloves

PATCH LOCATION	MICROGRAMS PER LB AI MIXED Mean	Coef of Var	Geo. Mean	Obs.
HEAD (ALL)	127.9871	495.5875	4.1314	122
NECK.FRONT	23.0158	362.6609	1.7263	104
NECK.BACK	15.5714	383.462	.5412	110
UPPER ARMS	157.6735	903.2036	1.4925	90
CHEST	19.0359	263.976	3.4214	90
BACK	10.8933	223.0206	1.8685	89
FOREARMS	4.4266	211.9821	.8927	84
THIGHS	16.6064	198.1742	3.9823	72
LOWER LEGS	37.8101	824.4477	1.1046	82

Subset Name:
S5DERMAL.MLOD

[a] subset criteria included actual and estimated head patches. Of the 122 head observations, 96 were actual and 26 were estimated from nearby patches (Versar, 1992).

Table 5-2. PHED data from dermal, hand, and inhalation subsets for Scenario 5[a]

Exposure Category	Exposure (µg/lb AI handled)	Replicates in subset	Short-Term Multiplier[b]	Long-Term Multiplier[b]
Dermal (non-hand)[c]	433	90[d]	4	1
Hand (with gloves)	58.2	59	4	1
Inhalation	2.35	85	4	1

[a] results from subsets of Mixer/Loader data in the Pesticide Handlers Exposure Database (PHED). Results rounded to three significant figures.
[b] multipliers are explained in the text and in Frank (2007).
[c] dermal total includes addition of default feet value of 0.52 x (value for lower legs); ratio of feet/lower leg surface area (U.S. EPA, 1997).
[d] median number of replicates was used in determining subset multipliers.

Table 5-3. Values in Scenario 5 Exposure Calculations[a]

	Short-Term Exposure	Long-Term Exposure
Total Dermal	4(433) + 4(58.2) = 1,960 µg/lb AI handled	1(433) + 1(58.2) = 491 µg/lb AI handled
Inhalation	4(2.35) = 9.40 µg/lb AI handled	1(2.35) = 2.35 µg/lb AI handled

[a] values from Table 5-2. Results rounded to three significant figures

Appendix B-5: Mixer/Loader, Open System, Dry Flowable (with gloves)

Table 2-1. Description of PHED subsets for Scenario 2[a]

Parameter	Specifications used to generate subsets[a]	Actual characteristics of resulting subsets
Data Quality Grades[b]	A,B	A,B,C
Solid Type	Dry flowable	Dry flowable
Mixing Procedure	Open	Open

[a] subsets of Mixer/Loader data in the Pesticide Handlers Exposure Database (PHED). Parameter descriptions are from screens displayed in the PHED program.

[b] data quality grades for Airborne, Dermal Uncovered, Dermal Covered and Hand are all Grade A or B, with the exception of one dermal replicate that has Dermal Uncovered Grade C (Dermal Covered for that replicate is Grade B). Data quality grades are defined in the text and in Versar (1992).

Figure 2-1. Summary of results from the Pesticide Handler Exposure Database (PHED) dermal subset for Scenario 2[a]

SUMMARY STATISTICS FOR CALCULATED DERMAL EXPOSURES

SCENARIO: Long pants, long sleeves, gloves

PATCH LOCATION	MICROGRAMS PER LB AI MIXED Mean	Coef of Var	Geo. Mean	Obs.
HEAD (ALL)	30.5021	124.7406	11.9921	19
NECK.FRONT	13.9106	102.7059	5.8389	16
NECK.BACK	3.2942	170.3236	.7453	19
UPPER ARMS	8.3504	98.8935	6.5856	23
CHEST	8.9296	67.003	6.7856	26
BACK	6.786	73.1388	4.8789	26
FOREARMS	3.7089	66.0196	3.0986	23
THIGHS	90.2695	296.5869	11.3605	26
LOWER LEGS	17.8317	298.7707	4.2874	26

Subset Name:

S2DERMAL.MLOD

[a] subset criteria included actual and estimated head patches. Of the 19 head observations, 16 were actual and 1 was estimated from nearby patches (Versar, 1992).

Table 2-2. PHED data from dermal, hand, and inhalation subsets for Scenario 2[a]

Exposure Category	Exposure (µg/lb AI handled)	Replicates in subset	Short-Term Multiplier[b]	Long-Term Multiplier[b]
Dermal (non-hand)[c]	193	23[d]	4	1
Hand (with gloves)	9.74	21	4	1
Inhalation	0.655	23	4	1

[a] results from subsets of Mixer/Loader data in the Pesticide Handlers Exposure Database (PHED). Results rounded to three significant figures.

[b] multipliers are explained in the text and in Frank (2007).

[c] dermal total includes addition of default feet value of 0.52 x (value for lower legs); ratio of feet/lower leg surface area (U.S. EPA, 1997).

[d] median number of replicates was used in determining subset multipliers.

Table 2-3. Values Used in Scenario 2 Exposure Calculations[a]

	Short-Term Exposure		Long-Term Exposure	
Total Dermal	4(193) + 4(9.74) =	811 µg/lb AI handled	1(193) + 1(9.74) =	203 µg/lb AI handled
Inhalation	4(0.655) =	2.62 µg/lb AI handled	1(0.655) =	0.655 µg/lb AI handled

[a] values from Table 2-2. Results rounded to three significant figures.

Appendix B-6: High Pressure Handwand Mixer/Loader/Applicator, Liquid (open pour)

Table 21-1. Description of PHED subsets for Scenario 21[a]

Parameter	Specifications used to generate subsets[a]	Actual characteristics of resulting subsets
Data Quality Grades[b]	A,B,C	A,B,C
Liquid Type	Not specified	Microencapsulated
Application Method	High pressure hand wand	High Pressure Handwand, Greenhouse/Ornamental
Mixing Procedure	Open	All open

[a] subsets of Mixer/Loader/Applicator data in the Pesticide Handlers Exposure Database (PHED). Parameter descriptions are from screens displayed in the PHED program.
[b] data quality for Airborne, Dermal Uncovered, Dermal Covered are all Grade A; Hand data are all Grade C. Data quality grades are defined in the text and in Versar (1992).

Figure 21-1. Summary of results from the Pesticide Handlers Exposure Database (PHED) subset for Scenario 21[a]

SUMMARY STATISTICS FOR CALCULATED DERMAL EXPOSURES

SCENARIO: Long pants, long sleeves, gloves

PATCH LOCATION	MICROGRAMS PER AVERAGE LB AI Mean	Coef of Var	Geo. Mean	Obs.
HEAD (ALL)	335.34	189.3598	108.1326	13
NECK.FRONT	684.7243	169.8879	240.7374	7
NECK.BACK	502.1311	169.8879	176.5408	7
UPPER ARMS	1000.3013	153.8867	353.808	13
CHEST	1220.2988	153.8867	431.6215	13
BACK	1220.2988	153.8867	431.6215	13
FOREARMS	415.9328	153.8867	147.1161	13
THIGHS	614.7471	125.9135	325.0308	7
LOWER LEGS	383.01	125.9135	202.5061	7

Subset Name:
S21DERMAL.MLAP

[a] subset criteria included actual and estimated head patches. Of the 80 head observations, 10 were actual and 70 were estimated from nearby patches (Versar, 1992).

Table 21-2. PHED data from dermal, hand, and inhalation subsets for Scenario 21[a]

Exposure Category	Exposure (µg/lb AI handled)	Replicates in subset	Short-Term Multiplier[b]	Long-Term Multiplier[b]
Dermal (non-hand)[c]	6,580	13[d]	5	2
Hand (with gloves)	339	13	5	2
Inhalation	151	13	5	2

[a] results from subsets of Mixer/Loader/Applicator data in the Pesticide Handlers Exposure Database (PHED). Results rounded to three significant figures.
[b] multipliers are explained in the text and in Frank (2007).
[c] dermal total includes addition of default feet value of 0.52 x (value for lower legs); ratio of feet/lower leg surface area (U.S. EPA, 1997).
[d] median number of replicates was used in determining subset multipliers.

Table 21-3. Values Used in Scenario 21 Exposure Calculations[a]

	Short-Term Exposure		Long-Term Exposure	
Total Dermal (with gloves)	5(6,580 + 339) =	34,600 µg/lb AI handled	2(6,580 + 339) =	13,800 µg/lb AI handled
Total Dermal (no gloves)[b]	5(6,580) + 50(339) =	49,800 µg/lb AI handled	2(6,580) + 20(339) =	19,900 µg/lb AI handled
Inhalation	5(151) =	755 µg/lb AI handled	2(339) =	302 µg/lb AI handled

[a] values from Table 21-2. Results rounded to three significant figures.
[b] gloves assumed to provide 90% protection (Aprea *et al.*, 1994); exposure of bare hands is calculated as ten times exposure of gloved hands.

Appendix B-7: Backpack Mixer/Loader/Applicator, Liquid (open pour)

Table 20-1. Description of PHED subsets for Scenario 20[a]

Parameter	Specifications used to generate subsets[a]	Actual characteristics of resulting subsets
Data Quality Grades[b]	A,B,C	A,B,C
Liquid Type	Not specified	Solution, Microencapsulated
Application Method	Backpack	Backpack
Mixing Procedure	Open	Open

[a] subsets of Mixer/Loader/Applicator data in the Pesticide Handlers Exposure Database (PHED). Parameter descriptions are from screens displayed in the PHED program.

[b] data quality for Airborne, Dermal Uncovered, Dermal Covered are all Grade A or B; Hand data are all Grade C Data quality grades are defined in the text and in Versar (1992).

Figure 20-1. Summary of results from the Pesticide Handlers Exposure Database (PHED) subset for Scenario 20[a]

SUMMARY STATISTICS FOR CALCULATED DERMAL EXPOSURES

SCENARIO: Long pants, long sleeves, gloves

PATCH LOCATION	MICROGRAMS PER AVERAGE LB AI Mean	Coef of Var	Geo. Mean	Obs.
HEAD (ALL)	345.2564	194.899	91.4483	11
NECK.FRONT	178.6391	155.1078	38.2719	11
NECK.BACK	1163.209	108.1731	611.9794	11
UPPER ARMS	10116.4827	239.4633	257.2654	11
CHEST	275.4477	170.903	65.7564	11
BACK	8918.1809	167.9854	1044.0635	11
FOREARMS	153.593	184.2219	30.0425	11
THIGHS	597.2782	282.8189	49.147	9
LOWER LEGS	425.8878	230.6324	64.6874	9

Subset Name:

S20DERMAL.MLAP

[a] subset criteria included actual and estimated head patches. Of the 11 head observations, all were actual.

Table 20-2. PHED data from dermal, hand, and inhalation subsets for Scenario 20[a]

Exposure Category	Exposure (µg/lb AI handled)	Replicates in subset	Short-Term Multiplier[b]	Long-Term Multiplier[b]
Dermal (non-hand)[c]	22,300	11[d]	6	2
Hand (with gloves)	9.68	11	6	2
Inhalation	17.5	11	6	2

[a] results from subsets of Mixer/Loader/Applicator data in the Pesticide Handlers Exposure Database (PHED). Results rounded to three significant figures.

[b] multipliers are explained in the text and in Frank (2007).

[c] dermal total includes addition of default feet value of 0.52 x (value for lower legs); ratio of feet/lower leg surface area (U.S. EPA, 1997).

[d] median number of replicates was used in determining subset multipliers.

Table 20-3. Values Used in Scenario 20 Exposure Calculations[a]

	Short-Term Exposure		Long-Term Exposure	
Total Dermal (with gloves)	6(22,300 + 9.68) =	134,000 µg/lb AI handled	2(22,300 + 9.68) =	44,600 µg/lb AI handled
Total Dermal (no gloves)[b]	6(22,300) + 60(9.68) =	134,000 µg/lb AI handled	2(22,300) + 20(9.68) =	44,800 µg/lb AI handled
Inhalation	6(17.5) =	105 µg/lb AI handled	2(17.5) =	35.0 µg/lb AI handled

[a] values from Table 20-2. Results rounded to three significant figures.

[b] gloves assumed to provide 90% protection (Aprea *et al.*, 1994); exposure of bare hands is calculated as ten times exposure of gloved hands.

Appendix C: Seasonality of Use for Simazine in Agricultural Fields, with a Focus on Its Implications for Handler Exposure

For all the agricultural handler groups considered in the present exposure assessment (i.e., for those listed in Tables 5 through 8), their seasonal as well as annual exposure frequency was set at 60 days, which was considered as a reasonable conservative estimate. The elaboration below, including a brief discussion on the general use of simazine, is to justify the use of this default frequency estimate and to explain why the Department's annual PUR (Pesticide Use Reports) data in the present case with simazine are inadequate or inappropriate for use to project temporal use patterns for handlers working in an agricultural (or even other) setting.

First of all, PUR data as constructed can only be as useful or as descriptive as listing the usage of each pesticide AI (active ingredient) by crop/site, county, acres treated, pounds applied, applications made, general application method used (i.e., aerial *vs*. ground), etc. As such, these PUR data cannot be utilized to project *directly* the exposure frequency of an *individual* handler. Yet more importantly, the PUR data were not considered useful or relevant here with simazine because the herbicide's use as specified in the labels is rather unique. Supporting this argument are the two observations or considerations given below.

<u>*Use of Simazine*</u>. This simazine AI is used primarily as a herbicide for control of a variety of *annual* broadleaf and grassy weeds. All of its product labels registered in California specify that it should be applied prior to weed emergence or after removal of weed growth. It is one of those herbicides inhibiting weed growth mainly *at the stage of seed germination or seedling establishment*. Herbicides of this type usually will not control annuals after the weeds begin to form leaves or after their seeds have germinated. Therefore, these herbicides are effective only if they are placed into the soil horizon where weed seeds start to germinate or will germinate. Normally, soil application for this type of herbicides is accomplished by soil incorporation, or by pre-emergence application followed by overhead irrigation (or rainfall, where weather permitting). According to the California Weed Conference (Rhoads *et al.*, 1989), the seedlings of annuals rarely emerge from the soil; and if they do emerge, they are usually stunted and deformed.

Weeds that complete their life cycle in one year or less are classified as *annuals*. This class is considered to pose the *most common* cultivation problems in agriculture, in that the species of annuals are *numerous* and that they have the ability to reproduce wildly around crops that grow or are planted annually. Weeds of this type are often subdivided into summer or winter annuals, depending on the time of year at which they begin to germinate and grow (Klingman and Ashton, 1975; Rhoads *et al.*, 1989). Summer or winter annuals normally are populated by seeds.

When summer annuals germinate in the spring, they grow actively during the summer months and die by the end of summer or early fall. The seeds that they produce in summer months often lie dormant in the soil until the next spring. By the same token, winter annuals germinate in late fall or early winter, and usually mature in the spring before they die in early summer. The seeds of winter annuals often lie dormant in the soil during the summer months (Rhoads *et al.*, 1989).

Pre-emergence herbicides including simazine control weeds by preventing the seedlings from becoming established. Again, to be effective, herbicides of this type must be applied before the weed seeds have a chance to germinate. The window of seed germination is very short for most any summer or winter annual, *typically less than 4 weeks* in each season.

Adequate soil moisture before and after application is necessary to activate simazine and most other pre-emergence herbicides. The effect of pre-emergence herbicides generally lasts no more than 10 to 12 weeks, given that these herbicides begin to degrade soon after they are exposed to the open environment. Therefore, to obtain season-long control, a reapplication should be made roughly two months after the first; and typically only 1 reapplication is needed again because of the rather short window of seed germination involved. Although product labels do not preclude the use of simazine on perennials that often live for three or more years, commercial applicators know well that the herbicide is effective only when it is used on pre-emerging annuals. These applicators and experienced growers are also supposed to be well aware of the *narrow* window of application timing for summer and winter annuals.

Implications of PUR Data. The latest available use data from PUR (DPR, 2013) indicated that based on ground application, Tulare and Fresno (in that order) were the two counties using the most simazine in California during the five-year period from 2006 to 2010. As indicated in Table C-1 below, in each of these two counties, November through March were the high-use months in which simazine usage was 5% (a cut-off used in the current practice at WHS) or more, and collectively represented nearly 90% of each county's five-year total. For Tulare, October was also treated as a high-use month as simazine usage in that month was slightly above 5%. Yet despite such a relatively large number of high-use months

Table C-1. Monthly Usage of Simazine in the Top Two California Counties via Ground Application, 2006-2010[a]

	Fresno		Tulare	
January	50,822	12.0%	92,348	17.4%
February	191,898	45.2%	113,524	21.3%
March	73,312	17.3%	56,910	10.7%
April	16,349	3.9%	17,733	3.3%
May	13,002	3.1%	4,678	0.9%
June	3,142	0.7%	1,080	0.2%
July	1,243	0.3%	797	0.1%
August	729	0.2%	2,296	0.4%
September	120	0.0%	2,873	0.5%
October	5,141	1.2%	36,849	6.9%
November	34,576	8.1%	118,669	22.3%
December	33,986	8.0%	84,056	15.8%
Total	*424,320*	*100.0%*	*531,812*	*100.0%*

[a] from the Pesticide Use Reports (DPR, 2013); monthly usage is in pounds for agricultural uses only (as the monthly usage in non-agricultural settings was comparatively and considerably less); each percentage is based on the five-year total.

observed, the use patterns as shown in Table C-1 must be interpreted both with caution and by taking into consideration other factors such as those discussed in the next paragraph.

For one thing, the PUR data presented in Table C-1 did not imply that simazine was used every single day *at the maximum daily* usage (as so conservatively presumed in the present exposure assessment) by a *single* handler in either county during the period from October or November through March (i.e., through the 5 or 6 so-called high-use months). Second, the window of seed germination is supposed to be less than 4 weeks for *each* weed species, meaning that growers are supposed to apply simazine *timely* during the *same* 2 to 3 weeks prior to seed germination for *each* weed species of concern. The monthly usages for January, February, and March observed in Tulare and Fresno were likely from the one *re*application made to prolong simazine's effects on winter annuals of the same species. As noted earlier, for certain species of winter annuals, seed germination may begin as late as early winter.

For the sake of (counter-)argument, it is possible for the simazine applications in Tulare or Fresno to be lined up in a way that a *single* operator would apply the herbicide for some 60 *consecutive* days from November to December, and then *re*apply the same herbicide once (or twice) for some 60 to 90 consecutive days from January to March. However, in order for this *one* operator to receive such a great business opportunity, he or she not only must be a highly reputable individual with good time management, but also has to know exactly *when* and *where* each of the numerous weed species in Tulare or Fresno begins to germinate. (More specifically, this person would have both the business and the knowledge of treating only species A, not species B (or C), in November as species A has a seed germination window of 3 or 4 weeks occurring in that month but not in December, and then treating only species B, not species A, in December as species B has a 3- to 4-week window occurring in that month but not in November or another month.) Moreover, the growers must be willing to take the risk that an initial application made in the *last few days* of the (4- week) window for seed germination is as effective as when it is made during the *early part* of that window.

Third, the data in Table C-1 above reflect a so-called 'high-use' trend of 5 or 6 months for at most one handler group considered in the present exposure assessment. This one group of operators was almost strictly those involved in *band* type ground application around tree crops. According to the PUR data in Table 3, these tree crops included primarily nectarines, avocados, oranges, olives, lemons, grapes, and walnuts. This explains why in California, especially in Tulare and Fresno, there were more simazine applications made in agricultural fields in the winter than in the summer months. In other words, this high-use trend is not applicable for other handler groups considered in the present exposure assessment. For one thing, this trend is not intended for *aerial* handlers because the data in Table C-1 excluded aerial applications. Nor could sprinkler-type chemigation be probable around well-established crops like fruit trees, as crops must remain uninjured from herbicidal action. On the other hand, only small-scale operations (e.g., those treating <10 acres per day) can afford the time to apply herbicides using handheld spray equipment, which typically would not endure a use seasonality longer than a month by a single M/L/applicator. This is because handheld spray application is a very time-consuming and inefficient process, compared to applications using a groundboom tractor. As stated earlier and repeatedly, the window for seed germination of summer or winter annuals is rather short, typically less than 4 weeks for each species.

Fourth, and more importantly, a further analysis of the PUR data in Table C-1 actually lent a strong(er) support for a maximum seasonal exposure frequency of less than 60 days for ground application. When the five-year data were further extracted by application date, grower ID, and application use number, they showed that in each month of these five years, not many days were associated with individual applications that each used 200 lb or more of the AI (as reflected by application date). Note that where such multiple applications occurred on the same day, only one of them was counted under the assumption that the same crew or worker would or could not apply such relatively large poundage in two different fields at the same time. The results of this further analysis are summarized in Table C-2, which support the estimates of 48 and 30 days as the average seasonal exposure frequencies for ground spraying in Tulare and Fresno, respectively, at least during the five years 2006 through 2010.

Table C-2. Daily Ground Applications That Each Used 200 lb of Simazine AI or More in Each Month in the Top Two California Counties, 2006-2010[a]

	2006	*2007*	*2008*	*2009*	*2010*	*Average*
			Tulare County			
January	16	4	8	11	9	*9.6*
February	6	15	10	4	13	*9.6*
March	5	2	8	4	5	*4.8*
April	4	3	0	1	1	*1.8*
May	1	1	0	0	0	*0.4*
June	0	0	0	0	0	*0.0*
July	0	0	0	0	0	*0.0*
August	2	0	0	0	0	*0.4*
September	3	0	0	0	0	*0.6*
October	0	0	2	5	2	*1.8*
November	14	12	12	8	2	*9.6*
December	14	13	7	5	6	*9.0*
Yearly	*65*	*50*	*47*	*38*	*38*	*47.6*
			Fresno County			
January	10	3	3	5	2	*4.6*
February	12	16	14	7	7	*11.2*
March	9	3	2	1	6	*4.2*
April	4	1	0	0	1	*1.2*
May	11	3	0	0	0	*2.8*
June	1	0	0	1	0	*0.4*
July	0	1	0	0	0	*0.2*
August	0	0	0	0	0	*0.0*
September	0	0	0	0	0	*0.0*
October	0	0	0	1	0	*0.2*
November	6	7	6	3	1	*4.6*
December	13	1	3	0	1	*3.6*
Yearly	*66*	*35*	*28*	*18*	*18*	*33.0*

[a] from further extraction of the PUR data (DPR, 2013) used in Table C-1, by application date and use number; AI ≡ active ingredient; 200 lb is simply 40% of the conservatively assumed maximum daily usage (= 5 lb AI/acre x 100 acres/day) for groundboom application.

In this further analysis, the focus was on individual *daily* applications using 200 lb or more of the simazine AI because (almost) all of the simazine products reportedly used for ground application were in some form of *liquid* formulation, and because the maximum daily usage assumed for ground spray was 500 lb (i.e., 5 lb liquid AI/acre for 100 acres/day). That is, when a single application involved less than 200 lb of the AI, then one or more of the handlers in that application would experience less than 40% of the exposure estimated on the basis of the defaulted full daily dosage. Such a "partial day" application would be deemed as insignificant for the purpose of determining exposure *frequency*. In other words, it would or should take 2 or more such "partial" days to make up 1 full exposure day to be qualified as 1 exposure frequency day for use to amortize the chronic dosage calculated (for the same person) in the present exposure assessment. Actually, about half of the ground applications listed in Table C-2 (i.e., those each involving 200 lb or more of the AI) were each found using less than 400 lb of simazine. The inclusion of these cases (each still with less than a full day exposure) was thus deemed sufficient to offset any underestimation made by excluding those cases each using less than 200 lb of the AI. It is also important to realize that, as for the reasons given earlier, not all cases listed in Table C-2 were likely handled by the *same* crew. Nor is it likely that those workers handling the applications included in Table C-2 were the same individuals that handled those applications excluded from the analysis (i.e., those each used <200 lb of the AI). In short, the use of 200 lb (of the AI handled per application) as the cut-point was actually biased towards having a health protective exposure frequency.

There are apparently not enough open field floors in California counties that would warrant a *full* broadcasting type of herbicide treatment (i.e., those warranting the use of chemigation or aerial equipment) for longer than 1 or 2 months per year. For example, the PUR data in Table C-3 show that for aerial application in Stanislaus, which was the highest-use county during

Table C-3. Monthly Usage of Simazine in the Top Two California Counties via Aerial Application, 2006-2010[a]

	Stanislaus		Mendocino	
January	19	0.7%	0	0.0%
February	0	0.0%	605	95.5%
March	0	0.0%	28	4.4%
April	190	6.1%	0	0.0%
May	0	0.0%	0	0.0%
June	0	0.0%	0	0.0%
July	0	0.0%	0	0.0%
August	0	0.0%	0	0.0%
September	0	0.0%	0	0.0%
October	0	0.0%	0	0.0%
November	1,140	36.8%	0	0.0%
December	1,747	56.4%	0	0.0%
Total	*3,096*	*100.0%*	*633*	*100.0%*

[a] from the Pesticide Use Reports (DPR, 2013); monthly usage is in pounds for agricultural uses only (as no non-agricultural aerial spray was reported); each percentage is based on the five-year total.

the five years from 2006 to 2010, the only high-use months were April, November, and December, with the five-year total for each of the three months having less than 1,800 lb of the simazine AI (and almost all occurring in the year 2010). It is clear from the Stanislaus data in Table C-3 that the simazine applications could easily be accomplished by a single crew in a few days in each month [= (<1,800 lb, the highest usage in December) x (2 lb/acre, application rate)$^{-1}$ x (200 acres/day/person, daily acreage per crew)$^{-1}$]. Note that the maximum application rate is 5 lb/acre and the maximum daily acreage per crew was assumed to be 600 in the present exposure assessment. That is, if the aerial applications were all done at these maximums, the highest monthly total of 1,747 lb simazine AI (in December, 2010) could be accomplished by a single crew in just 1 day.

As a final point of argument, despite the fact that the overall conclusion here is a statement of probability based on limited knowledge and professional judgment, its validity or reliability should not be viewed as any less than that of the projection made directly with PUR data. The main problem with the use of PUR data is the uncertainties over the correlation between usage in a county and frequency of pesticide application by a single operator in that county. More pounds of a pesticide used in a county in a given time period could imply more applications made or more applicators used, not necessarily more (re)applications made (and hence not necessarily more workdays spent) by a single handler (crew) during that time period. Special consideration must also be given when determining the high-use months (i.e., those reaching 5% of the total use) or the months that need to be included for annualizing chronic dosage. It is not realistic to blindly include the months that simply reached the cut-point percentage but that failed to use a sufficient amount of the pesticide or to cover a sufficient amount of the crop (floor). More bluntly, it is simply not realistic to include those months that each reflects mathematically a handling task that can be completed in a few days within a month by a single worker.